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ABSTRACT

The research reported in this project focuses on the effective development, evaluation and individualization of programed materials. The study involved three phases. Phase I was to determine which of four programing methods was most effective for the attainment of science achievement at three levels, knowledge, application, and relationship. Subjects were fourth and fifth grade students randomly assigned to the four treatments. Results indicated that the developmental presentations, Skinnerian and Ruleg, were more effective at the three achievement levels than the textual presentations. In phase II of the study, a flexible multi-variable computerized approach was developed to (1) determine the readability and (2) guide in the writing and revision of self-instructional materials. The definition and evaluation of three remedial branching conditions derived from the automated readability model was the focus of phase III. Forty-three fourth grade students were randomly assigned to the three treatments. A multi-variate analysis was used to evaluate the three treatments. Levels of achievement, error rate, time, intelligence, sex and experimental treatments were defined as predictor variables. Science achievement, at three conceptual levels, was defined as the criterion. The report contains also a reference section, a bibliography, and an appendix of data tables. (LC)

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FINAL REPORT

PROJECT NO. 6-1310

GRANT NO. OEG-2-6-06-1310-1743

METHODS OF PRESENTING PROGRAMED SCIENCE MATERIALS TO FOURTH GRADE PUPILS OF VARYING ABILITY AND ACHIEVEMENT

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June, 1970

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CHAPTER I

STATEMENT OF PURPOSE AND BACKGROUND

I. Introduction

The development of the programed approach and the more recent adaptation to computer-assisted instruction is one of the few educational innovations which has generated excitement from both researchers and educators. The awareness, concern and some alarm that a segment of our population is not being prepared to live in or adjust to a dynamic society in the midst of technological innovation, coupled with the increasing recognition that schools must pace and adjust the curriculum to hold the potential dropout, suggests the value of a self-instructional and individualized process. The researchers' enthusiasm for this approach can be illustrated by Suppes' (78) emphasis to use a computer-based system to bridge the gap between research in learning theory and curriculum, or the potential of programed materials suggested by Lumsdaine (49), to build a science of instruction.

It is likely, however, that the educator's continued interest in the self-instructional approach rests to a large extent on the realization of its potential. Although programed learning has encouraged a more systematic curriculum evaluation, the statement of behavioral objectives, and some modification of instructional procedures, the implementation of this approach has not always provided the individualization which was initially anticipated. A program which incorporates the features of individual pacing, immediate reinforcement, and active involvement is not necessarily any more effective than traditional methods. Moreover, the manipulation of programing variables does not always result in a more effective presentation of materials. Such conclusions, commonly reported in studies of programed learning and computer-assisted instruction, emphasize the need to identify more efficient ways to evaluate and guide in the writing, revision, and utilization of self-instructional materials.

In the past programed and computer-assisted instructional materials have been developed by trial and error. For example, a particular piece of computer assisted instructional materials would be written and then tested on a typical group. The results would serve as feedback for further revisions of the programs. These revisions, in turn, would require further revisions. This activity continued until the program functioned smoothly. This trial-and error approach is inefficient;

it is both costly and time consuming. The research reported in this project focuses on the effective development, evaluation, and individualization of programmed materials.

Phase I

Efforts to develop successful programing methods have led to the wide variation in the application of the principles of learning to materials development. However, program assessment studies have not generated a set of principles to guide in the selection of a programing technique. Learner characteristics and task variables are frequently not considered in identifying the appropriate programing technique. Phase I of the research activity responds to this need by an evaluation of four programing methods which accounts for individual differences and variation in conceptual attainment.

The study did not favor any particular programing method, but served as a pilot approach by selecting four programing methods from among the many techniques, and by relating the effectiveness of the method of presentation to the ability level and sex of the child and to the conceptual level of the behavioral objective. The four methods selected were: (1) developmental - Skinnerian, (2) developmental - RULEG, (3) textual counterpart of the Skinner type, and (4) textual counterpart of the RULEG presentation.

Phase II

Research studies tend to agree that reading difficulty is an important criterian for selecting textual materials; and, as such, textbook selection is an exceedingly important and difficult task. Reading difficulty is even more crucial to the students' success in using programed learning. The significance of the reading factor and the absence of a formula adapted to the programed approach prompted the research activity of Phase II of the reported research. The major objective of this phase of activity was the development of an automated analysis to manage programed materials development which includes a synthesis of both programing and readability variables.

Phase II of the research activity identifies 25 independent readability and program variables which are descriptive of the frame structure, response characteristics, and the content presentation and organization of programed materials. The automated procedures sort, locate, and accumulate a count and listing of the independent variables from the context of the programed materials. After a printout of the variable counts and word listings is obtained, the independent variables are related to student error rate (validated against student ability and achievement measures). The readability formula is described by an equation of the best predictors of error rate. Thus descriptive data are presented for all variables, those readability variables significantly related to student performance are identified, and the nature of the relationship is established.

The automated feature and related analysis offer specific advantages to the production of programmed materials (1) either directly, in the writing, revision, and refinement of materials; (2) or through program definition and experimentation, which yields an understanding of why a program modification is more or less effective.

Firstly, the analysis offers direct assistance to writing and revision procedures in the following ways: (2) the automated feature and predicted student error rate reduce the time lag and expense created by field testing and manual counts; (b) the analysis of the entire text allows the identification of differences among the writing practices of programers, the differences among units, hierarchies, or sequential organization; (c) the summary data and analysis suggest revisions specific to the program context, hence avoiding the trial and error often associated with program modification, unrelated to student performance or the relevant contextual variables.

Secondly, the readability analysis relates to the experimentation in programed learning. The identification of significant frames, response, and content presentation and organization variables, and the relationship of these variables to student performance, provides a comprehensive definition of program structure and an evaluative model of program adaptations. The use of such a model avoids the ambiguities often associated with program descriptions, such as Skinnerian, small step, etc. Silberman (72) has stated the need for an adequate program description as follows, "Ideally, it would be desirable to identify specific structural features of programs which invariably contribute to their effectiveness. This would greatly simplify the evaluation of programs; unfortunately, such relationships have not been established." This concern is echoed by Glaser (30) who recommends a set of terms or a taxonomy for describing the properties of a particular program and the differences between programs."

The need for a comprehensive and objective model of program structure is attested to be fragmented research findings, studies of isolated variables, difficulties encountered in generalizing beyond a given set of materials, and evaluation procedures which are typically restricted to changes in criterion behavior, neglecting an assessment of the relative influence of program features. The automated analysis offers a promising approach in program definition and evaluation. Objective counts on contextual data (frame, response, content presentation and organization variables) and a knowledge of the influence of these program features allow the investigator to objectively describe his materials and to relate programing, readability and/or psychological approaches to a common model of program structure. As such he can establish the nature of a branching condition and distinguish genuine differences in program methods from those approaches in which the primary difference appears to be one of semantics.

Phase III

The definition and evaluation of three remedial branching conditions derived from the automated readability model of program structure is the focus of Phase III. The first branch adaption, knowledge of, describes the lexical component, and is designed to reduce the negative influences of vocabulary difficulty and technical terminology. The second two branching conditions are directed toward structural components, sentence and topical.

In this study there is an evaluation of a hierarchy of branching conditions that encompasses what has often been labelled under psychological learning variables. It has been commonly recognized that learning is related to IQ levels. This means that, in learning at a certain level of abstraction or difficulty, further teaching activity is required to make clear and comprehensible a piece of material to the student. With programmed learning this goal is often accomplished by branching.

When branching is used, the level of reading difficulty should go down so that a student can master material that was previously too difficult for him to understand. But what often happens is the reverse: the reading difficulty increases with the use of branching conditions. The material becomes more difficult and is harder to learn. Such an occurrence is of course self-defeating, for branching should make any material more comprehensible than it was previously.

There are several possible explanations why branching increases the level of reading difficulty (decreased readability). More and more detailed questions are asked in order to clear up a perplexing point. Often this means that, in a branching condition, the material moves from facts to principles and ideas to explain the facts. This stress on principles and ideas rather than facts may be a key factor in decreased readability because principles and facts are usually more difficult to understand than facts. Moreover, asking questions about a certain point, even if not at a new difficulty level involving principles and ideas, may lessen the readability because it may be harder for a student to see the relationship of the new questions to the original perplexing point.

In any event, whatever may be the factors that result in decreased readability, the important thing is to determine when the readability has gone up or down and how it can be changed. The problem is not merely to hold readability constant when branching is used, but rather to decrease the level of reading difficulty so that a student may understand the material that he previously found perplexing. A fully developed readability model, we believe, will enable one to determine when readability increases or decreases in a branching condition. And having a criterion for determining reading difficulty will bring together a number of loose ends--the psychological variables--that have been felt to contribute to reading difficulty.

Branching conditions in our program can be viewed as a three-fold hierarchy, with each level or branching condition more difficult, complex, and abstract, than the previous level. The first level deals with specific terms, especially mathematical and scientific, and general vocabulary. Students at this level acquire, in a word, knowledge of concepts. At the second level an analysis is made of sentence length and structure. Relationships between concepts are reviewed. A "global" presentation or preview describes the third branching condition.

II. Developments by the Bureau of Educational Research

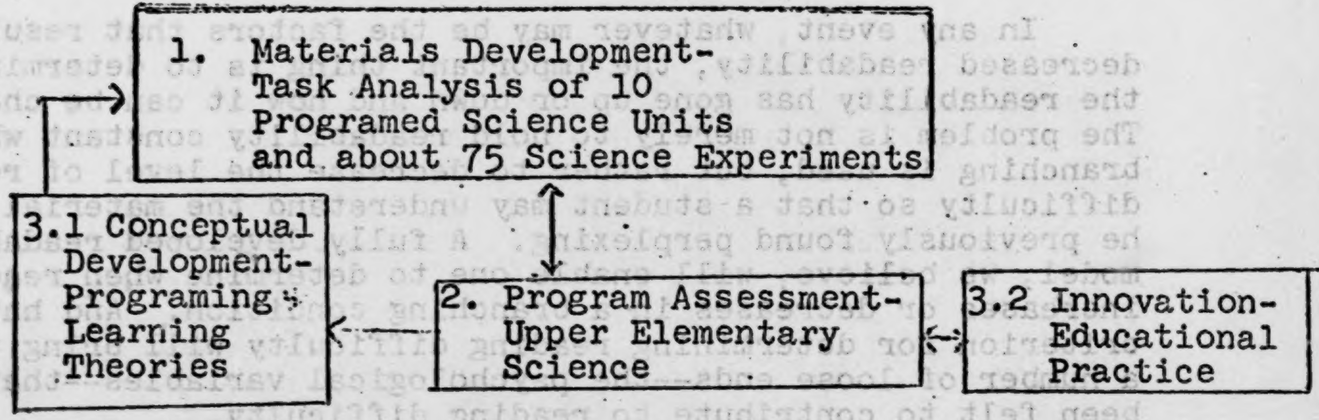
The renewed interest in science education in the 1950's focused on the extremes in quality and quantity of the science being taught and the concern of many teachers who had not anticipated the recent scientific emphasis in their training. A survey of the status of science in the Virginia elementary schools, conducted by the Bureau of Educational Research in 1963, and a follow-up study evaluating the objectives of science teachers in Virginia combined and secondary schools identified areas of critical need within the state (35). The theoretical developments and expanding applications of programed learning during the same period suggested a possible approach to the re-evaluation of the science curriculum and to an improved science instruction.

In 1962, the Bureau of Educational Research initiated a series of studies to test the efficacy of programed science materials at the fourth-grade level, coupled with an investigation of the influence of the individual performance by pupils of simple science experiments as they complete framed sections of the programed materials. Figure I summarizes the research strategy, 1962-1969.

Stages 1 and 2, Materials Development and Program Assessment, established the feasibility and instructional effectiveness of the programed science materials (19), (36).

Figure 1

RESEARCH STRATEGY - 1962-69



		1. Materials Development-Task Analysis of 10 Programed Science Units and about 75 Science Experiments	
A. Research Functions	3.1 Conceptual Development-Programing & Learning Theories	2. Program Assessment-Upper Elementary Science	3.2 Innovation-Educational Practice
B. Research Objectives	B.3.1a Establish the relationship between programing techniques, learner characteristics & conceptual levels B.3.1b Develop a model of program structure; readability, program definition & experimentation	B.2a Ascertain the feasibility & instructional effectiveness of the programed approach B.2b Revise; materials (1); identify research needs for materials refinement, (3.1); Relate instructional procedures & student behaviors to stage (3.2)	B.3.2a Implement and demonstrate the programed approach within context of the Elementary School B.3.2b Incorporate program features within an instructional system (Fig. 2)
C. Activities	C.3.1 Adaptation to CAI for instructional pruposes (approx. 150 students) & for use as a research tool to store, collect & analyze contextual & student data	C.2 Pilot and Field Studies under several programing conditions carried out in over 50 classes.	C.3.2 The training, supervision & implementation of the programed-centered approach in 24 upper elementary classes
D. Funding Research Completed:	D.3.1 CRP# 6-1310 Investigator: MacDougall; (June, 1966-March, 1968) $64,940 Federal Support, $91,039 Instit. Support. Extension to June, 1969, and Planned Research: Jacobson & MacDougall. Related Research: Computer-Simulated Law Games - Milton Jacobson, Oct. 1968-Oct. 1969 Small Grant Proposal	D.2 CRP# 1972 Investigators: Hedges & MacDougall; (1963-1965). $33,000 Federal Support. Institutional Support. One-year extension $12,000 Federal Support	D.3.2 CRP# 6-1319 Investigator: MacDougall; (June, 1966-Sept. 1967). $33,351 Federal Contribution $17,209 Local Contribution

A one year's course of instruction, ten programed science units and approximately 75 experiments, was developed and field tested under several programing conditions in over 50 upper elementary classes (37). The reliability and validity of ten unit tests and a final true-false science achievement test were established. The instructional effectiveness of the programed approach was measured by science interest, attitudes, laboratory resourcefulness, science achievement and retention, and critical thinking skills.

Although the feasibility of this approach was established, the investigators were not able to demonstrate that this approach was generally superior to conventional teaching (with supervisory assistance). The investigators concluded that the laboratory experiences contributed in large measure to the sustained motivation of students over one year, as well as contributing to their ability to solve new problems; critical thinking skills were likewise shown to significantly improve. The vast majority of students remained positively oriented toward the programed approach throughout the course of study. Student behaviors and related instructional procedures were identified and recorded for use in subsequent training and supervisory activities.

Valuable side effects to teaching science observed during the field testing prompted a demonstration study to use this approach in the training of elementary teachers (54). Stage 3.3, Figure I, focuses on this objective. In contrast to the background studies in which the role of the teacher was prescribed to monitor the programed materials, a demonstration project was designed to encourage individual adaptation of the programed science approach within an organized instructional pattern. Major concerns were (1) classroom organization for the teacher's participation in the programed instructional process, and (2) the integration of classroom procedures and activities complementary to the experiences of the children who progress at an exceptionally fast rate or who are retarded by low reading ability.

The evaluation of the demonstration study recommended this approach as an effective way to (1) introduce new scientific content into the elementary science program, (2) include the use of laboratory experiences in the science curriculum, (3) individualize instructional procedures, and (4) involve supervisory and administrative personnel in the elementary science program. A one year follow-up in 1967-68 of seven fully participating classes using several modified approaches confirmed the previous year's recommendations.

The research reported in this study is summarized under stage 3.1, Figure I. Three science units were adapted to a computer assisted instructional system and four programing techniques were pilot tested and evaluated (53). Another study was carried out in 1967-68 by the Bureau of Educational

Research (39), (71). A program for the B5500 computer facility at the University of Virginia was written into which units of the programed science materials were read; automated counts of seventeen independent variables (measuring the frame structure, the density of technical terms, and the content and organization of the text) were obtained. The number of errors that each student made in the programed units were tabulated from programed materials. Error count, traditionally used as a measure of reading difficulty, was defined as the criterion variable. Error count was found to be highly related to other measures of achievement, including standardized tests.

This project was designed to develop procedures of general applicability for measuring the reading difficulty of programed materials and to develop formulae directly applicable to the reading difficulty of fourth-grade programed science materials.

The materials consisted of nine fourth-grade programed science units which had been prepared at the Bureau of Educational Research. From the nine units three -- (1) sound, (2) light, and (3) heat -- were selected because more pupils completed this set of units than any other set. The programed science materials were used in twenty elementary schools in central Virginia during the school year 1966-67. The make-up of the students was 440 sixth graders, 171 fifth-graders, and 789 fourth graders.

The independent variables were synthesized from an analysis of more than 200 previous studies in readability and an analysis of over 50 studies of programed learning. The variables were defined so that they could be determined automatically by a computer and could be related by means of a multiple regression equation to the reading difficulty of the programmed science materials. A listing of the variables follows. The categorization is twofold. The first eight variables (X_1 - X_8) are the traditional reading variables. The next nine (X_9 - X_{17}), however, are programming variables, and their isolation and analysis is an especially important aspect of our model. The development of this model is presented in chapter II. Our later model, Model II, expands the total number of variables to 25 and provides a better predictability and rationale for selection than our initial study did (40), (41). The development and applications of model II are presented in chapters II and III.

III. Review of Literature

Four Program Versions

Variables commonly classified under frame characteristics (step size, error rate, prompting and item position) and response variables (response made, type, rate and variation of reward and reinforcement) are components of programing techniques frequently identified to further refine and explain the efficacy of a programing technique (47), (48). However, a review of those studies investigating the influence of program variables on student performance suggests inconsistent findings or results which are not significant (31), (67), (68), (69), (72).

One major difficulty arises in the study of the effects of a program variable in attempts to define and isolate the independent variable(s) under investigation; i.e., an increase in step size is usually accompanied by a reduction in the number of reinforcements. From a summary of investigations, one can observe the interrelationships among the variables, which are suggestive of methods of programing, such as the Crowder or Skinner-type presentations. For example, small step, logical presentation is successful with knowledge of results or confirmation, while a less ordered or larger step approach may be compensated for by an explanation of a correct or incorrect response. Likewise, step size can be increased without loss in criterion achievement if responses are meaningful. There is evidence that overt responses may interfere with complete prompting, while prompting or cueing within limits appears successful.

Because of the interrelationships among the programing variables, and in the absence of evidence which indicates the power of any one programing variable, this study proposed to investigate methods of presentation, as opposed to the influence of isolated variables. The two developmental techniques are based on the Skinner and RULEG systems. The textual counterparts of these systems incorporate features of the Crowder approach.

Skinner-Holland Technique. Step characteristics can be described as small step, cueing, likelihood of correst response, and logical arrangement. Response mode and feedback are described by immediate feedback, overt, constructed response. Discrimination training assumes importance in the linear versions (75), (76).

The RULEG System. Developed by Evans, Homme, and Glaser, (20), the Ruleg system of programing divides all verbal subject matter into two classes of statements: (1) rules to be learned, and (2) examples or illustrations. As in Skinner's approach, the program is ordered and the steps are not usually longer than two sentences. A matrix is used to standardize the presentation of basic relations among the materials to be programed, and an additional matrix is constructed for each operator (relationship, discrimination). Rules and incomplete examples are at first prompted and then fading is introduced. The Ruleg System generally defines the basic concepts early in the program. As soon as a student demonstrates his ability to respond (by constructed response), the prompts are withdrawn. New information is expanded and varied.

Two differences between the Skinner program and the Ruleg system are: Ruleg is more adaptable to use of negative or opposite examples, and movement toward a concept is rapid after indication of the student's correct response. The successive approximations used in Skinner's technique move the subject slowly to concept formation.

Multiple choice programing. Norman Crowder in his use of the scrambled book, sometimes referred to as intrinsic programing, does not emphasize step size, etc., but uses a student's response to direct his behavior. Student responses can be modified or corrected and strengthened, where explanation of error, rather than prevention of error, is emphasized (14), (15).

Sydney Pressey (64), (65), (66) has continued to use multiple choice responses, and like Crowder, does not emphasize size of step or ordering. He disagrees with Skinner on the prevention of wrong answers and his work with testing instruments as instructional aids suggests that he views programed learning as an adjunct, rather than a replacement of, the more traditional methods of instruction.

The four methods of presentation evaluated in Phase I are defined as follows:

1. Developmental-Skinner type. The method is composed of a set of linear frames which follow the Skinner-Holland Technique, and is similar to that of Keislar, whose use of successive approximations and prompts suggest a likeness to the Skinner program.

2. Developmental-RULEG. This technique was developed by Evans, Homme and Glaser, and is composed of a set of linear frames which classify verbal behavior into rules to be learned (RU) and examples (EG).

3. Textual - prompting. Essentially a textual counterpart of (1) above.

4. Textual - explanation. Essentially a textual counterpart of (2) above.

Presentations (1) and (3) rely more heavily on prompting and cueing; presentations (2) and (4), rules or explanations. The developmental presentations require a student response after each frame. The textual presentations were included to ascertain if the use of a computer-based system requires the students' responding to each frame, or can be as effectively used for testing, branching and monitoring.

The evaluation of the four presentations considered variation in student ability levels, since there is conflicting evidence that a single presentation is equally effective for all students (7), (10), (17), (32), (55). Studies illustrative of the influence of difficulty levels on student performance (12), (21), (60), and the structural features of the four program versions suggested that the criterion behavior be classified into levels of conceptual attainment. This study identified the levels, knowledge, application, and relationships.

More than 200 reading difficulty investigations have been made since 1800. Among the important summaries and reviews of previous reading studies are Gray and Leary's (33) textbook which reviewed the literature up to 1935, Chall's (11) and Klare's (44) articles reporting studies up to 1959 and 1963 respectively and the 47th Yearbook, Part II, of the National Society for the Study of Education and Reading Research Quarterly (83) which makes annual reviews of all aspects of reading. Although four major factors--vocabulary, sentence structure, idea density, and human interest--are identified in these studies as related to reading difficulty, most of the attacks on reading problems have been concentrated on vocabulary.

Perhaps the most important vocabulary studies were done by Thorndike when he developed his lists of 10,000, 20,000, and 30,000 most common words in the English language (79). These lists have been used by most investigators of vocabulary difficulty. Several other major word lists were constructed by Buchingham and Dolch (9), and Lorge (46). The latter has shown frequency of words (in lists) to be positively related (R = .51) to the readability of passages in material.

In 1928 Vogel and Washburne (80) created the first formula which related difficulty factors of written materials to specific reading levels. A regression equation related four factors of difficulty to the grade level of books. The four factors were the number of different words in a 1000 word sample, the number of words outside Thorndike's 10,000 word list (both measured the vocabulary difficulty), the number of sample sentences (which measured the sentence structure), and the number of prepositional phrases (which measured the idea density). This noteworthy study involved a general attack on reading difficulty. A decade later, in 1938, the formula was revised.

Johnson (42) demonstrated the relationship of reading levels to the number of syllables in a word. In an experimental study using elementary reading material, the substitution of monosyllabic for polysyllabic words resulted in increased comprehension.

In 1943 Flesch (22) found that the widely used Lorge and Gray-Leary formulas were inadequate for adults with more than limited average ability because the formulas did not differentiate between levels of difficulty of materials. The Flesch formula, a modification of the Lorge and Gray-Leary formulas, could be applied with greater ease and it discriminates between adult materials more effectively than the Gray-Leary or Lorge formulas.

Dale and Chall (1948) found that the number of words which were not in Dale's 3000 word list correlated higher with the criterion variable (grade-level score equivalent) than did either the Lorge or Flesch formula, and with average sentence length as a second independent variable the correlation was .70. Yoakam (82), working at the elementary level, found that his readability formula and the Dale and Lorge formulas gave substantially the same results. A study by Spache, mentioned because of its wide usage in elementary schools, and because it was partly validated with science books, established the difficulty of books by the grade level in which they were to be used. Bormuth (4) developed and refined a new technique (Cloze Procedure) for determining readability and extended this work to include new independent variables from linguistics studies. Although his variables showed good relationships they are extremely difficult and laborious to determine.

Summarizing the readability formula studies, the reading difficulty factors are:

1. Vocabulary load. This may be estimated by such criteria as the number of syllables, number of letters per word, number of abstract words by lists. These factors are intercorrelated.

2. Sentence structure. This may be estimated by the average sentence length and the percentage of simple sentences.

3. Idea density. This may be estimated by the number of prepositional phrases.

4. Human interest. This may be estimated by the number of personal references, personal pronouns, and personal sentences.

These formulas predict readability with correlations which range from .4 to .7. A major criticism of these formulas is the widespread misapplication of them to materials for which their valid use had not been demonstrated. In addition, most of them are inadequate for determining reading levels of difficult or technical material.

Readability of Science Materials

Another basic shortcoming is that these studies were not necessarily related to the reading of science material. Of greater relevance for determining the readability difficulty of science materials are the studies by Pressey (63), Powers (62), Curtis (16) and Mallinson (51). They discovered that vocabulary difficulty was directly related to achievement in science studies.

Pressy found out that the large technical vocabulary in science textbooks was an obvious source of difficulty to students in science courses. Powers utilized Thorndike's 20,000 word list to obtain a list of words in science textbooks which were not in the first 10,000 words of Thorndike's list. He developed a list which offered a starting point for authors of textbooks in science who sought to limit textbook vocabularies.

Mallinson carried out several studies to investigate reading difficulty in various kinds of science textbooks. A follow-up study ten years later found that the reading difficulty of most textbooks is too high, supporting the initial findings. Herrington's (34) study showed the undesirability of an indiscriminate application of the Flesch, Lorge, and Dale-Chall formulas to upper level materials in science.

More recent studies by Marshall (52) and Major (50) attempted to determine the validity of using Flesch's formula to evaluate the comprehension difficulty of physics and biology textbooks. Warringer identified specific factors which cause difficulty in physics and biology textbooks.

Marshall's study showed that Flesch's Reading Ease Formula does not predict the difficulty of comprehension of high school physics textbooks. Major modified passages from textbooks using the Flesch formula, and found that increased achievement by students was due to the reduction of sentence length and reduced number of syllables. He found the Flesch formula offers a valid instrument to measure the reading difficulty of science texts and a procedure for modifying (a priori) these materials to increase achievement.

Jacobson (38) compared the popularity of physics and chemistry texts with an experimental determination of their reading difficulty. The study removed the effect of the order of the sample materials and simplified and extended the number of variables that Warringer (81) had used to develop a reading equation. Four regression equations were developed which validly predicted the reading difficulty of physics and chemistry textbooks with a degree of accuracy comparable to that with which general material is predicted by widely used general readability formulae.

Smith and Heddens (77) concluded that the reading difficulty of mathematics materials is too high and great diversity exists among materials written for the same grade levels. Fourth grade mathematics materials, for example, ranged from the third to the seventh grade level. The authors found considerable differences among the Flesch, Dale-Chall, and Spache formulas.

Summarizing the results of past readability studies, one notes that vocabulary difficulty and sentence length are significantly related to the readability of technical materials. However, variables of greater significance to technical materials include the use of symbols, mathematical terms, subject and unit differences. A valid measure of the reading difficulty of technical materials requires the application of a formula which is specifically developed for mathematical and scientific subjects.

Relationship of Programing Variables to Readability Analysis

The automated program and analysis of reading difficulty provides an objective and comprehensive definition of program structure by the presentation of word listings and counts on the variables which define frame structure, response characteristics, and content presentation and organization, and by an analysis of the relationships between the independent variables and the criterion, student error rate. This section summarizes the relationship between those programing and readability variables included in the automated analysis.

Frame Characteristics. Programing variables commonly associated with a study of frame characteristics are step size, error rate, and prompting. The readability variables which define Frame Structure (number of paragraphs, sentences, words, letters, frames) offer a specific and objective definition of step size. A comprehensive interpretation of error rate can be obtained from an analysis of the relationships of the independent variables with the criterion, error rate, and the validation of error rate with achievement and ability measures. The variables, number of frames which contain a word identical to the response alternative and number of frames in which the same technical work appears more than once, are two indications of prompting.

Response Characteristics. Programing studies of response characteristics often include a comparison of the effects of overt vs. covert responses, multiple choice vs. constructed response, the influence of a meaningful response, and reward. The response variable, per cent of response frames, identifies the overt-covert emphasis. The influence of a meaningful response and other response modes can be observed by the influence of the independent variables, number of frames with math and scientific terms as responses, number of responses with yes-no, true-false response alternatives, number of one-three word response alternatives, and placement of response on student error rate. Since the programed materials adapted to the computer utilize only the multiple choice responses, the multiple choice vs. linear feature is not included in the readability formula; however, program modifications can be designed for materials with more than one response mode.

Content Presentation and Organization. The content words or lexicon of the program text is represented by variables measuring the density of mathematical and scientific terms. Overlap is defined as the number of consecutive instances of technical word overlap. The syntax is described by three types of sentence structures.

The variables of the revised version of the readability formula (Model II) are summarized below.

Category I: Frame Characteristics. Six variables which measure paragraph, sentence and word length, vocabulary difficulty, and number of frames per sample.

Category II: Response Characteristics. Six variables which describe the number of response frames, the nature and relevance of the response.

Category III: Content Presentation and Organization. Five variables which measure density of mathematical and scientific terms, overlap and repetition.

Category IV: Sentence Structure or Syntax. Seven variables which identify three sentence types, the average number of words and technical words per sentence type. The remaining independent variable identifies the science unit.

Criterion Variable. The average number of errors per sample.

Branching Rationale

The revisions of most frame and response variables hold a direct relationship to the readability model and a quantitative modification can be directly applied to lower the student error rate. However, modification of content presentation and organization variables may not be as apparent—or even possible. An example of a relatively fixed variable, the density of scientific words, may contribute to reading difficulty, although the curriculum may strongly suggest the need to include the terminology. Less apparent revisions may also be indicated when error rate is not changed or is not accompanied by improved achievement. Lastly, the relationship with ability may suggest individual adaptations of a qualitative nature.

In the absence of a taxonomy of human learning (56), the readability model is proposed as an evaluative model of branching conditions. Programing techniques or branch adaptations can be selected to either compensate for the negative effects of a relatively fixed readability variable, or to make a contribution to individual or general performance beyond that accounted for by the readability formula. Those studies pertinent to the development of the three branching conditions evaluated in this research project are summarized below.

Gagne (24) has emphasized sequencing of programed materials as an essential factor in concept acquisition and retention. The importance of the learner achieving success on each task component has been demonstrated by Gagne and his associates, who have analyzed learning from a "task analysis" approach (23).

Silberman and Coulson (73), (74) in reporting on the empirical development of programs in reading, arithmetic, Spanish and geometry, attempted to define optimal procedures to be used in program revision. Three principles, the "gap," "irrelevancies," and "mastery" principles, support the "task analysis" of Gagne; however, Silberman and Coulson accept both sequencing and individual adaptation to achieve mastery, while Gagne emphasized sequencing techniques.

Ausubel (2) supports the use of advance organizers, or sorting and classifying models. He urges the use of expository and comparative organizers in the organization of programed materials. In the case of material organized along parallel lines, he suggests that comparative organizers are expressly designed to further the principle of integrative reconciliation; i.e., by pointing out in what ways previosly learned, related ideas in cognitive structure are either basically similar to or essentially different from new concepts in the learning task.

Branching is a common method to accommodate individual differences. Initial experimentation by Coulson and Silberman indicated a saving of time for the branching group, but no significant mean differences in post-test scores. They attributed this result to branches of essentially more of the same presentation; thus, students made the same kinds of errors on branches as they had on the initial presentation. Later experiments (13) indicate that Coulson and Silberman find superiority in branching versions. Gilman and Gargula (29), using review branching in the Computer Assisted Instruction Laboratory, The Pennsylvania State University, conclude there must be a thorough investigation of those situations where branching facilitates learning and the criteria for branching decisions must be determined. The authors found no advantages for a branching strategy and cited studies by Holland, Campbell, and Glaser which are consistent with their results. They point out that these results are not consistent with those found by Skinner, Holland and Porter, Evans and Barlow.

The programing approaches discussed under content presentation and organization evidence individual success in modifying student behavior. However, the present definitions of program and organizational features do not clearly distinguish among methods, nor do empirical findings clearly support a rationale which specifies the selection of an instructional strategy or curriculum adaptation to the programed context. A study by Merrill and Stolurow (57) compared six preview and review treatments and found the "summary prior condition" the most effective instructional procedure. The authors conclude that this finding supports both Ausubel's concept of advanced organizers and Gagne's hierarchial presentation. The assumptions that mastery is achieved by successive attainment and integration of lower level learning sets, and program modification is accomplished through sequencing techniques (27), (58) are not consistent with studies (28), (45), (61), which randomize frame presentation with no loss in achievement; qualification of the mastery principle and the use of sequencing techniques may be indicated. Little is known about the selection and presentation of a branching condition; although despite conflicting evidence, the efficacy of individual adaptation to achieve mastery has been reported. A study (1) which finds an interaction between the gap and mastery principles and between the irrelevancy and mastery principles suggests the difficulty in defining program variables within the context of the material. Some of the inconclusive results likely stem from the use of a rationale which does not embrace alternative methods and from the need for an evaluative model of program structure.

The programing concerns related to context presentation and organization have much in common with a discourse analysis, or the movement of sentences and their relationship to each other. A paper prepared for the Appalachia Regional Laboratory (18) presents a discussion and analysis of the conventions a writer employs which have their result in lexical, structural, cultural and rhetorical components and constraints. The authors identify the lexicon and structure as primary expressive components in the presentation of information or content. A brief statement of the discourse analysis which follows is restricted to those lexical and structural features most relevant to a programed analysis of a suceessful presentation of scientific content.

A discussion of the lexical component distinguishes content words from structure (or function) words. The topic reflects the integration of the lexical items into a larger form in the structural environment, these words linked together by lexical equivalents or chains. The structural components include (a) sentence structure and structural patterns; (b) structural words, e.g., words signaling a connection, constraint, negation, causality, alternative, etc., and integrators, here, it, that, which; and (c) constraints, a linguistic determinism or limitation, the purpose of which is to define, rather than diffuse the topic.

In an analysis of material for first year children, those recommendations which refer to the lexical and structural components are repetition through lexical equivalents and repitition of structures within a consistent and coherent design. The authors warn against structural ambiguities which create a cognitive gap when a structural signal is omitted (e.g., because) to reduce sentence length; or in the interests of simplification, the use of an integrator (e.g., this) when its meaning is not clear. The gap, mastery and irrelevancies principles are implicit in a repetitive lexicon and structure, and in sources of structural ambiguity. A dominant lexical chain and the analysis of constraints to direct, rather than diffuse, both earlier and later material, recognizes the value of sequencing and the notion of a preview and hierarchical design.

The rationale of the three branching conditions evaluated in Phase III of the study is presented below.

Adaptation 1. Knowledge of - Lexical Component

Scriven's (70) conceptual description of educational objectives (cognitive) is selected as a general statement of the tasks required of the program:

Knowledge of:

a) Items of specific information included definitions of terms in the field.

b) Sequences or patterns of items of information including sets of rules, procedures or classifications for handling or evaluating items of information (we are talking about mere knowledge of the rule or classification and not the capacity to apply it.)

Rationale. Readability studies have consistently shown that vocabulary and technical terminology contribute to reading difficulty and achievement. Textual adaptation of these variables has been successful. The readability formula includes measures of general vocabulary difficulty and the density of mathematical and scientific terms. It is assumed that revision procedures can offset any negative influence of general vocabulary;however, since knowledge of technical terminology is often necessary to an understanding of a technical subject, scientific and mathematical terms are defined as the lexical component for which the curriculum will be adapted.

The adaptation is designed for more effective concept acquisition for students with a relatively low verbal ability. Early studies, as well as later experimentation (26), indicate that a knowledge of terminology is most difficult to retain. The branch as a method of overlearning or review may improve retention generally or distinguish among student ability levels. The learning capability and condition is based on Gagne's definition of the concept of the simpler type or concept by observation and classification (25).

Adaptation 2. Comprehension of - Structural Component/Sentence

The general statement of tasks, from Scriven (70), is as follows:

Comprehension and Understanding of:

> Internal relationships in the field, i.e., the way in which some of the knowledge claims are consequences of others and imply yet others, the way in which the terminology applies within the field; in short what might be called understanding of the intro-field syntax of the field or subfield.

Rationale. Readability studies have commonly found sentence length and sentence structure significantly related to reading difficulty. However, where reduction in sentence length or complexity results in ambiguity or a cognitive gap, repetition of sentence structure may be recommended. Comprehension of the ordered relationship between two concepts is defined as the structural component for which the curriculum will be adapted. The learning capability and condition relates to Gagne's definition of a principle (25) and repitition of lexical chaining in the discourse analysis (18).

Adaptation 3. Comprehension of - Structural Component/Topical

The general statement of tasks, from Scriven (70) is presented as follows:

Comprehension or Understanding of:

Application of the field or the rules, procedures, and aoncepts of the field to appropriate examples, where the field is one that has such applications; this might be called the semantics of the field.

Rationale. Application or semantics of the field as the educational objective of the third adaptation is related to the structural component which contributes to the reader's understanding by constraining his focus and direction (rather than diffusing) the topic. (18) The constraint of earlier as well as later material is adapted to the curriculum by the contrast and comparison of principles. The branching condition follows Ausubel's use of advanced and comparative organizers (2).

IV. Statement of Objectives

Phase I

The evaluation of the four program versions (Skinner-type, Ruleg, and the textual counterparts of each developmental presentation) was carried out to identify the technique(s) most effective for the attainment of science achievement. The analysis focused on the following two objectives.

1. What is the relationship between the four programing versions and the science achievement of fourth and fifth grade students?

2. What are the learning conditions which describe the relative success of each of the four presentations?

The criterion, science achievement is defined by three levels of conceptual development, knowledge, application, and relationship, and total achievement. Learning conditions consider learner characteristics and program quality. Intelligence and sex are identified as measures of the learner. Differences in achievement and error among the four presentations and between the two programed units (heat and light) suggest variation in program quality.

Phase II

The following objectives were specified in the development and implementation of the automated readability analysis.

1. Abstract and classify from readability and programed learning studies those independent contextual variables to be automatically determined by the readability analysis. Validate the independent variable classifications.

2. Develop a computer program which sorts, locates, and accumulates a count and testing of the independent variables from the context of the programed materials.

3. Implement the readability analysis by relating the independent variables to error rate. The readability formula is described by an equation of the best predictors of error rate.

4. Apply the automated readability analysis to the Skinnerian and Ruleg programs (Phase I) and to the programed unit which incorporates the three branch conditions (Phase III) in order to objectively define the program structure and to distinguish similarities and differences between programing techniques. Determine if the assumptions of sequencing are met.

Phase III

A fully developed readability model requires individual adaptations which decrease the level of reading difficulty. The objectives outlines under this phase of research activity are as follows.

1. Derive a branch rationale from the automated analysis.

2. Evaluate the branching conditions:

(1) Knowledge of - Lexical Component, (2) Comprehension of - Structural Component/Sentence, (3) Comprehension of - Structural Component/Topical.

3. Include in the evaluation control for intelligence, sex, time, error rate and science achievement levels (knowledge, application, relationships).

CHAPTER II

METHODS AND PROCEDURES

Presented in Chapter III are the procedural steps followed in the eveluation of the four program versions, the development, application and validation of the automated readability analysis, and the assessment of the three branching conditions.

I. Four Program Versions

Preliminary to the evaluation and analysis was the writing of the four program versions.

Materials Development

Two of the previously developed programed science units, heat and light* were each rewritten using the four presentations:

1. Developmental: Skinner-type
2. Developmental-RULEG
3. Textual-prompting
4. Textual-explanation

The versions were first used on a pilot basis and then were adapted to an IBM 1460 computer system. The developmental branches (1 and 2) required the student to respond to each frame. The summary treatments (3 and 4) were essentially a textual counterpart of the developmental versions. All students received the same subtesting series and remedial branches (if test scores indicated) on the computer, and all were engaged in the individual student performance of simple science experiments.

Sample and Measurement

The experimental period was initiated in September, 1967. Students matched by ability (Lorge-Thorndike intelligence test) and grade level (fourth and fifth) were randomly assigned to the four treatments: n=56, heat unit; n=48, light unit.

Learner characteristics were measured by his ability and sex. The time to complete the unit (in minutes), the error rate and subtest science achievement were gathered on each student.

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*See Boykin (6) for a study of achievement, feedback, and review on retention and transfer, using the sound unit.

In order to evaluate the level of conceptual attainment, each achievement item in the subtest series was classified into three levels, using Bloom's Taxonomy (3):

Level 1 - knowledge of corresponds to Level 1 in Bloom's Taxonomy
Level 2 - comprehension of corresponds to Levels 2 and 3 in Bloom's Taxonomy
Level 3 - relationship corresponds to Levels 4 and 5 in Bloom's Taxonomy

Analysis

A multiple regression technique (5) was used to evaluate the relationship between the four program versions and the level of conceptual attainment. Learner characteristics were included in the analysis as predictor variables.

II. Development of Automated Readability Analysis

The development of the automated readability analysis was carried out in three major phases. First the computer program was written and extended. Secondly, the computer program was applied to the elementary programed science materials. Lastly, the automated analysis was validated.

Development of Computer Program

The procedures followed in writing the computer program were as follows:

1. The content of programed science units is analyzed by a computer program, developed by the Research Bureau, using alphabetic and numeric characters which simultaneously sort, locate, and accumulate content and response data.

2. The program gives a table of all variable counts, means, and standard deviations, and word listings coded to page and frame.

3. After the printout of variable counts is obtained, a stepwise regression technique is used to determine the influence of the 25 independent variables on the criterion, error rate, and to obtain a multiple regression equation which gives the best prediction of error rate.

4. The error rate was validated against intelligence and science achievement(71).

Application of the Computer Program

1. After the development of the computer program, the automated technique was applied to an analysis of elementary programed science materials. Model I, developed in 1967-68, is presented as an initial prototype of this model.

2. The independent variables were synthesized from an analysis of more than 200 previous studies in readability and an analysis of over 50 studies of programed learning. The variables were defined so that they could be determined automatically by a computer and could be related by means of a multiple regression equation to the reading difficulty of programed science materials. The variable categorization of Model I is twofold. The first eight variables (X_1 - X_8) are the traditional reading variables. The next nine (X_9 - X_{17}), however, are programing variables, and their isolation and analysis is an especially important aspect of our model.

The variables defined by Model I and examples of this model are presented below.

MODEL I

Traditional Reading Variables

X_1: Average number of paragraphs per frame per sample.

X_2: Average number of sentences per paragraph per sample.

X_3: Average number of words per sentence per sample.

X_4: Average number of letters per word per sample.

X_5: Average number of simple sentences per sample.

X_6: Average number of words per sample which were outside Thorndike's list of 6000 words (measure of difficult words).

X_7: Average number of mathematical and scientific words (terms) per sample.

X_8: Average number of mathematical and scientific numerals or symbols per sample.

Programing Variables

X_9: Percent of frames that were response frames per sample.

X_{10}: Percent of response frames that were structures response frames per sample (frames which contain blanks for responses with a designated number of words in answer.)

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X_{11}: Percent of response frames that were free response frames per sample (frames which require a sentence or more to answer).

X_{12}: Percent of frames that were non-response frames per sample.

X_{13}: Percent of responses requiring mathematical or scientific words per sample.

X_{14}: Average number of frames using same key word or phrase consecutively per sample.

X_{15}: Average number of words in phrase per average number of words in phrases in succeeding frames (measure of redundancy).

X_{16}: Average number of disjoint frames per sample.

X_{17}: Average number of review frames per sample.

Y_1: The criterion variable, average number of errors per sample.

The multiple regression equation which gave the best prediction of Y (error count) with deletions of the insignificant variables, was

$$Y = 0.02129989\ X_7 + 0.00217358\ X_9 + 0.05553026\ X_{17} \ldots .06129922$$

where: X_7 = Average number of mathematical and scientific words (terms) per sample.

X_9 = Percent of frames that were response frames per sample.

X_{17} = Average number of review frames per sample.

The preliminary work done in this pilot project (Model I) indicates that the direction of the research is promising (71). The three variables of most significance were X_7 (average number of mathematical and scientific words or terms per sample), X_9 (percent of frames that were response frames per sample), and X_{17} (average number of review frames per sample). Two are programing variables whose relationship to reading difficulty had not previously been understood. Additional information obtained by testing would allow one to determine both the significance and stability of the other variables used in this pilot study, as well as the significance and stability of the additional variables that have been incorporated in our revised program (Model II).

As an example of Model I consider the following data consisting of six frames taken from a page in a computer based program system.

Example: MODEL I

Data - - - - - - - - (page)

84. The ________ of a light wave is as fast as anything we know about. Some cars can go over a 100 miles per hour. Light ________ travel faster than this. Light waves travel faster than cars, planes or sound ________. Light can travel in waves at great speed measured in ______ per ________. Light can travel over 186,000 miles in one ________. The speed of ________ is 186,000 miles per second.

This data is usually punched in natural language format onto IBM cards and input to the computer (many other inputs are permitted). The computer program processes the data and determines the variables automatically, determines a text list (indexed), a reply list (indexed), and a readability regression equation.

The print-out of the program for our example data was as follows:

```
                  AUTOMATED VARIABLE DETERMINATION

Total number of letters                    296
Total number of words                       73
Total number of sentences                    7
Total number of paragraphs                   6
Total number of frames                       6
Number of response frames                    6
Number of structures frames                  6
Number of free response frames               0
Number of non-response frames                0
Number of review frames                      0
Number of disjoint frames                    4
Number of non-disjoint frames                2

TEXT LIST
                 Pg. No.        Frame No.
A                0084:01        0084:02
About            0084:01
Anything         0084:01
As               0084:01        0084:01
At               0084:04
Can              0084:02        0084:02        0084:04        0084:05
Cars             0084:02        0084:03
Fast             0084:01
Faster           0084:02        0084:03
Go               0084:02        0084:02
Great            0084:04
Great      0084:04
Hour       0084:02
In         0084:04      0084:04      0084:05
Is         0084:01      0084:06
Know       0084:01
Light      0084:01      0084:02      0084:03      0084:04      0084:05
Measured   0084:04
Miles      0084:02      0084:05      0084:06
Much       0084:02
Of         0084:01      0084:06
One        0084:05
Or         0084:03
Over       0084:02      0084:05
Per        0084:02      0084:02      0084:06
Planes     0084:03
Second     0084:06
Some       0084:02
Sound      0084:03
Speed      0084:04      0084:06
Than       0084:02      0084:03
The        0084:01      0084:06
This       0084:02
Travel     0084:03      0084:04      0084:05
Wave       0084:01
Waves      0084:03      0084:04
We         0084:01
100        0084:02
186000     0084:05      0084:06

REPLY LIST

Light      0084:06
Miles      0084:05
Second     0084:04      0084:05
Speed      0084:01
Waves      0084:02      0084:03
```

Consider a more comprehensive example which resulted from 100 pages of programmed text input to computer program. From our initial pilot study (Model I), the following data were obtained. In this analysis 18,994 words and 100 pages of text were analyzed in less than a minute. The printout of the automated variable determination and the regression equation are shown below.

```
          AUTOMATED VARIABLE DETERMINATION (for 100 pages material)

Total Number of Letters                                 79926
Total Number of Words                                   18994
Total Number of Sentences                                1677
Total Number of Paragraphs                               1012
Total Number of Frames                                    902
```

Number of Response Frames	813
Number of Structured Response Frames	808
Number of Free Response Frames	4
Number of Non-Response Frames	89
Number of Review Frames	75
Number of Disjoint Frames	149
Number of Non-Disjoint Frames	753

A regression equation was established where the variables are the eight traditional and nine programing variables:

$$\begin{aligned} Y_t = {} & 0.04633829X_1 - 0.02973254X_2 + 0.00454001X_3 \\ & + 0.00061298X_4 + 0.00372806X_5 + 0.00616356X_6 \\ & + 0.02764715X_7 - 0.01622660X_8 + 0.00253719X_9 \\ & - 0.00166194X_{10} + 0.00224255X_{11} + 0.00003604X_{12} \\ & - 0.00209173X_{13} + 0.01192024X_{14} - 0.000076549X_{15} \\ & + 0.01679752X_{16} + 0.05149266X_{17} - 0.06742650 \end{aligned}$$

This regression equation related the independent variables to the criterian variable (error rate) with a multiple correlation coefficient ($R = 0.573$) comparable to those of other widely used reading equations cited in the literature.

3. The later model, Model II, expands the total number of variables to 25. The variables are defined below and applications of the automated analyais are presented in Chapter III.

MODEL II

The variables of the revised version of the readability formula (Model II) are presented below:

Category I: Frame Characteristics

X_1: Average number of paragraphs per frame per sample.

X_2: Average number of sentences per paragraph per sample.

X_3: Average number of words per sentence per sample.

X_4: Average number of letters per word per sample.

X_5: Average number of words per sample which were outside a standard text, i.e. Thorndike's list of 6,000 words. This is a measure of difficulty words. A'dictionary'of any kind can be generated to determine the frequency and difficulty of a word.

X_6: Average number of frames per page.

Category II: Response Characteristics: Relevancy

X_7 : Per cent of frames that are response frames per sample.

X_8 : Per cent of frames with math and scientific terms among alternative responses per sample.

X_9 : Per cent of frames with word in frame identical to response alternative.

X_{10}: Per cent of frames with yes-no or true-false response alternative.

X_{11}: Average number of frames in which response is placed within frame (as opposed to last word).

X_{12}: Per cent of frames with one word or phrase (1-3) as response alternative.

Category III: Content Presentation, Organization, and Overlap or Repitition

Density of Mathematical and Scientific Terms

X_{13}: Average number of mathematical and scientific words (terms) per sample.

X_{14}: Average number of letters per technical word.

X_{15}: % of frames in which the same technical term appears more than once.

X_{16}: Average number of frames in which the same technical word appears consecutively.

X_{17}: Average number of consecutive instances of technical word overlap.

Category IV: Sentence Structure or Syntax (Average number of sentences containing the following kinds of words)

X_{18}: Integrators: this, that, it

X_{19}: Signals: because, but, although, as since, when, then, next, consequently, however, either

X_{20}: Comparative: than

X_{21}: Average number of words per sentence, X_{18} sentence type

X_{22}: Average number of words per sentence, X_{19} and X_{20} sentence type

X_{23}: Average number of technical words per sentence, X_{18}

X_{24}: Average number of technical words per sentence, X_{19} and X_{20}

X_{25}: Science unit

Y_1 : The criterion variable: average number of errors per sample.

The independent variables were synthesized from an analysis of the probable causes of reading difficulty and a description of the basic kinds--literary and technical--of reading material.

X_1 was chosen because the paragraph is the first major division of the frame and paragraphs serve the purpose of separating introductory material from material requiring a response.

X_2 was chosen to indicate the length of an introduction.

X_3 was chosen because average sentence length has been found as a variable contributing to reading difficulty

X_4 was included because mathematics and scientific words tend to be longer than common words. That is, polysyllabic words are longer and more difficult than monosyllabic words.

X_5 was included because previous readability studies have found this listing to measure general vocabulary difficulty.

X_6 was selected as general frame of reference to step size.

X_7 - X_{12} were selected to identify relevance of response structure:

X_7 is a measure of overt response;

X_8 and X_{10} are measures of response relevance;

X_{11} and X_{12} indicate placement and nature of response structure;

X_{13} - X_{15} were selected to describe the density of mathematical and scientific words. These words are defined as having a scientific or technical meaning and are drawn from behavioral objectives of programed materials.

X_{16} - X_{17} were chosen to measure overlap or describe how closely content or lexicon is linked within structure

$X_{18} - X_{24}$ were chosen to describe the sentence structure and determine whether the nature of the structure creates ambiguity (this, that, it) or difficulty (connectors, comparatives), (X_{18}, X_{19}, X_{20}); or whether difficulty results from a concomitant of sentence structure, technical terms and sentence length ($X_{21} - X_{24}$).

X_{25}. identifies a biological or physical science unit to determine whether reading difficulty is common to all units.

Y_1 was selected because it gives a measure of readability directly related to each frame and is commonly related to achievement measures.

Variables $X_1 - X_6$ (Category I) are criteria for determining the overall structure and complexity of any page of printed material. These variables point out not only the most general features of a piece of reading material--number of frames per page and number of paragraphs per frame--but also pinpoint quite specific features such as the number of letters per word, number of words per sentence, and number of sentences per sample. Further, since the basic atomic unit of any sort of discourse is a word, it is important to know whether or not a word is common. This information is provided by variable X_5. Again, these variables in Category I are ways of pinpointing the structure and the components of the structure of any piece of printed material. The remaining variables in Categories II, III, and IV facilitate an analysis of the properties of the components of the structure of any reading material.

Of any material that is to be learned one important property is the kinds of responses that a student can make to questions about the material. Variables $X_7 - X_{12}$ (Category II) provide a thorough and systematic account of the sorts of responses that a student can make.

In analyzing any reading material a rough and general classification can be drawn up by labelling the material either literary or technical. If the material is technical, then it is important to specify in what way and what the relationship of one piece or section of technical material is to other technical material. Variables $X_{13} - X_{17}$ (Category III) do yield this sort of information. An especially important function of these "technical variables" is that they determine not only what are the technical words in a frame and their degree of complexity but also, and perhaps more importantly, determine the relationship of the technical words to one another in different frames, i.e., the degree of overlap. There are two principal reasons for wanting to find out what the degree of overlap is. First, the degree of repitition and reinforcement that may be needed can be established after overlap is measured. Secondly, the extent of dependency of later frames on earlier frames can be spelled out if it is known how frequently technical words or terms are used serially in a program.

Finally, variables X_{18} - X_{25} in Category IV provide a syntactical analysis of reading material. They enable one to specify how complex any sentence is in terms of relational words auch as pronouns, conjunctions, and adverbs. This function can be determined for both literary and technical material.

4. Applications of Model II, presented in Chapter III, include an (1) automated analysis of the heat unit, Skinner vs. Ruleg, (2) an automated analysis of the heat unit which incorporated three branching conditions, and (3) a check to satisfy the assumption of good sequential development; i.e., as students progress through the unit, is there an increase in the number of errors and the number of mathematical and scientific terms.

5. A principle components factor analysis was completed with varimax rotation (43) to validate the four categories hypothesized in the definition of independent variables.

III. Three Branching Conditions

The three treatment affects or branching conditions are based on those readability variables and psychological approaches which have evidenced success in the promotion of learning. The treatments are as follows:

Adaptation 1. Knowledge of - Lexical Component

Objective. Knowledge of terminology is described by Scriven (70) and measured by Level 1 in Bloom's Taxonomy (3).

Placement. A branch will be included (in half the programs) after the presentation of each technical term.

Learning Capability and Condition. The capability is described by a conceptual development which requires vocabulary and classifying behavior and corresponds to Gagné's concept by observation (25). The branch condition will include vocabulary reinforcement and the introductinn of additional examples and non-examples.

Adaptation 2. Comprehension of - Structural Component/Sentence

Objective. Comprehension or understanding of a principle is described by Scriven (70) classification 2a. - application of terminology within the field or intrafield sytax. Items will be classified using Levels 3 and above (application, analysis, synthesis, evaluation) in Bloom's Taxonomy (3).

Placement. The development of principle which relates to two or more concepts concludes each hierarchy. The branching condition will be introduced (in 1/3 of the programs) after the completion of the hierarchy.

Learning Capability and Condition. Gagné's (25) definition of a principle which requires recall of component concepts and their correct ordering describes the type of human learning of major concern to the second application. The discourse analysis (18) likewise recommends repitition of lexical chaining and sentence structure. The branch presents a review of the relationship of the concepts with the principle, in which the student is presented with additional examples of the ordered or underlying relationships and the sentence structure necessary to express the relationships.

Adaptation 3. Comprehension of - Structural Component/Topical

Objective. Comprehension or understanding of a principle is described by Scriven's (70) classification 2c. - the semantics of the field, and measured by Levels 3 and above, Bloom's Taxonomy (3).

Placement. At the end of each hierarchy is a principle. Branching conditions will be introduced (in 1/3 of the programs) at the end of each hierarchy.

Learning Capability and Condition.. The learning capability is the understanding of a principle. The condition, the comparison and contrast of a principle at the end of each hierarchy with the principle to be introduced in the next hierarchy describes a preview or a review in which a previously presented principles is integrated with the new material of the succeeding hierarchy. This condition will follow Ausubel's use of advanced and comparative organizers, and his principle of integrative reconciliation (2).

The three branch adaptations were incorporated in the heat unit. The study was initiated in the fall of 1968. Forty-three fourth grade students were assigned to the following three treatment conditions: (1) no branching condition; (2) comprehension branches only - adaptations 2 or 3; and (3) knowledge and comprehension branches - adaptation 1 in combination with either adaptation 2 or 3. Time limitations precluded the number of student participants necessary to isolate the influence of each of the comprehension branches; i.e., adaptations 2 and 3 were observed as one treatment effort.*

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* See Moody (59) for an application of the automated analysis and branching conditions to two programed units included in the BSCS special materials. His branch conditions were found to be significant and he accounted for over 80% of the learning difficulty of slow learners using the automated analysis.

A multivariate analysis (5) was used to evaluate the three branching conditions in which the predictor variables were defined as levels of achievement, error rate, branch adaptations, time, intelligence and sex. The criterion variables were defined as total achievement and achievement at each of the three levels, knowledge, example and application, and relationships.

IV. Implications for Management Design

In summary, the procedures outlined above hold promise for the design of a management system for self-instructional materials development. The relationahip of the automated readability analysis and hierarchy of branching conditions to student direction and revision decisions is presented in Figure 2. The results presented in the following chapter suggest, with further field testing, that the full potential of this model can be realized.

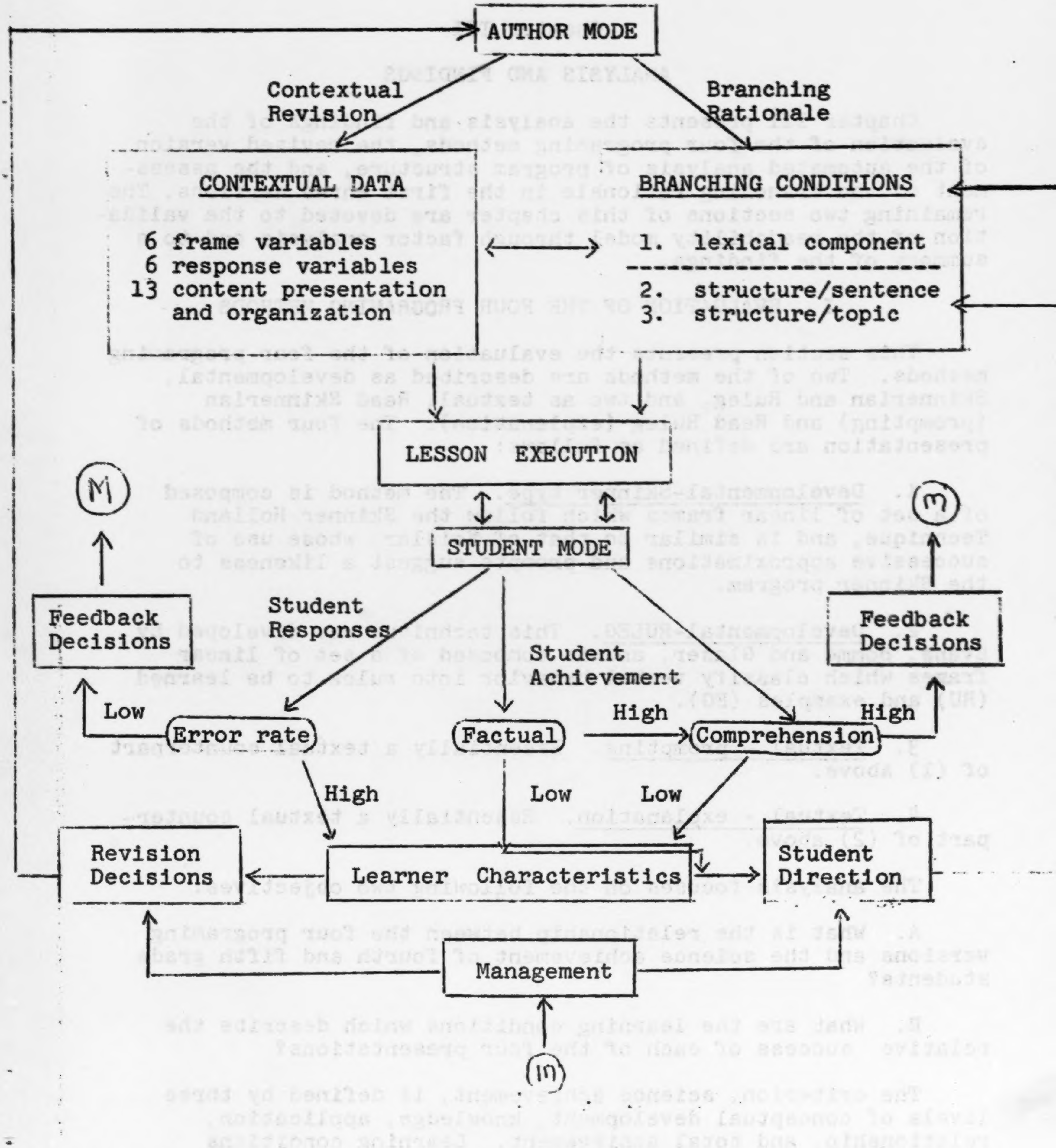
AUTHOR MODE
Contextual Revision
Branching Rationale
CONTEXTUAL DATA
6 frame variables
6 response variables
13 content presentation and organization
BRANCHING CONDITIONS
1. lexical component
2. structure/sentence
3. structure/topic
LESSON EXECUTION
STUDENT MODE
M
M
Feedback Decisions
Student Responses
Student Achievement
Feedback Decisions
Low
Error rate
Factual
High
Comprehension
High
High
Low
Low
Revision Decisions
Learner Characteristics
Student Direction
Management
M

Figure 2. Management Design

Chapter III

ANALYSIS AND FINDINGS

Chapter III presents the analysis and findings of the evaluation of the four programing methods, the revised version of the automated analysis of program structure, and the assessment of the branching rationale in the first three sections. The remaining two sections of this chapter are devoted to the validation of the readability model through factor analysis and to a summary of the findings.

I. EVALUATION OF THE FOUR PROGRAMING METHODS

This section presents the evaluation of the four programing methods. Two of the methods are described as developmental, Skinnerian and Ruleg, and two as textual, Read Skinnerian (prompting) and Read Ruleg (explanation). The four methods of presentation are defined as follows:

1. Developmental-Skinner type. The method is composed of a set of linear frames which follow the Skinner-Holland Technique, and is similar to that of Keislar, whose use of successive approximations and prompts suggest a likeness to the Skinner program.

2. Developmental-RULEG. This technique was developed by Evans, Homme and Glaser, and is composed of a set of linear frames which classify verbal behavior into rules to be learned (RU) and examples (EG).

3. Textual - prompting. Essentially a textual counterpart of (1) above.

4. Textual - explanation. Essentially a textual counterpart of (2) above.

The analysis focuses on the following two objectives:

A. What is the relationship between the four programing versions and the science achievement of fourth and fifth grade students?

B. What are the learning conditions which describe the relative success of each of the four presentations?

The criterion, science achievement, is defined by three levels of conceptual development, knowledge, application, relationship, and total achievement. Learning conditions consider learner characteristics and program quality. Intelligence and sex are identified as measures of the learner. Differences in achievement and error rate (error rate can only be gathered for the developmental versions) between the light and heat units, as well as among the four presentations, suggest variation in program quality.

A multiple regression technique* of the form $Y = a_1X_1 + \ldots a_{25}X_{25} + K$, where the X's are the values of the independent variables, the a's are the regression coefficients, and the K is the constant for the equation, was used to test the null hypotheses of the form,

X_i (where $i = 1, 2, 3 \ldots n$) does not contribute to the regression equation to predict the reading difficulty as determined by average number of errors per sample ($a_i = 0$).

The F-statistic, .05 level of significance, is utilized to establish rejection or acceptance of the null hypotheses (ratio of regression means square to residual mean square). Using the F-ratio and the multiple R's a routine of single and multiple deletions establishes the combination of variables which best predict Y. The key to variables analyzed is presented in Appendix A.

Predictor variables were defined as:

$X_2 - X_3$ = achievement at levels 1 and 2, respectively

$X_5 - X_8$ = four programing versions

$X_9 - X_{10}$ = heat and light units

X_{11} = intelligence

$X_{12} - X_{13}$ = sex

X_{14}- = error rate

The criterion variable was defined as science achievement (% of correct items on subtests), where

Y_1 = total achievement

Y_2 = achievement at Level 1 - knowledge

Y_3 = achievement at Level 2 - example and application

Y_4 = achievement at Level 3 - relationship

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*Robert A. Bottenberg and Joseph H. Ward, Jr. Applied Multiple Linear Regression, Technical Documentary Report PRL-TDR-63-6 (March, 1963).

REGD, Adapted to B5500 computer, U. of Va., by Milton D. Jacobson.

The significance of the independent variables is reported relative to the influence of the predictor variables included in each analysis. For example, if I.Q., error rate, and program versions are defined as the predictor variables of achievement, and the variable, program version, is declared significant (at a given probability level), this finding is interpreted as a significant influence of program versions on achievement beyond that accounted for by intelligence and error rate. Thus, the predictor variables control for possible initial differences and concomitant variation. Analyses were run to identify possible interaction effects; no significant variation attributed to interaction effects was observed.

The analysis of data is presented under three sections. First, differences in program and unit quality are observed to establish if subsequent analyses will treat units and programs separately. Secondly, the four programing versions are evaluated; and lastly, the two developmental programs are compared.

Unit Differences - Heat vs. Light

1. Are there differences in achievement between the two units (heat and light)?

A. Considering only those students assigned to the two developmental branches and controlling for intelligence and error rate, it was found that the unit difference between heat and light significantly influenced science achievement at all levels (See Appendix B, Table V). Achievement favored the light unit.

B. The influence of the unit difference and error rate on levels of science achievement was determined for each of the four program versions with intelligence and sex controlled. The following results are summarized from Tables V - VIII, Appendix B.

Developmental

Skinnerian	- unit difference (heat vs. light) does not influence achievement at levels 1 and 3. Achievement in light is superior at level 2 and total. Unit differences account for the influence of error rate on achievement levels.
Ruleg	- Achievement in light unit is significantly greater at levels 2 and 3 and total achievement. Error rate influences

total science achievement, levels 1 and 3, beyond that accounted for by unit differences.

Textual

Read Skinner - Read Ruleg - No significant differences in achievement were found between the two units at level 1 and total; achievement at levels 2 and 3 significantly favored the light unit.

In summary, these findings indicate: (1) the light and heat units differ in quality with achievement favoring the light unit; (2) the influence of error rate, beyond that accounted for by unit differences suggests that the Ruleg program may be either a less effective method of presentation than the Skinnerian, or the writing of this unit has created sources of reading difficulty for the subjects and (3) the Skinnerian version is less influenced by unit differences than the Ruleg program. Unit differences are crucial at both comprehension levels (levels 2 and 3, application and relationships) for the textual versions.

It can be observed from TABLE I that student attainment was generally more successful for the light unit.

TABLE I

SCIENCE ACHIEVEMENT BY TREATMENTS AND LEVEL OF CONCEPTUAL DEVELOPMENT

Light Unit

	Total	level 1	level 2	level 3
Skinnerian	95	98	95	93
Ruleg	91	94	92	90
Read Skinnerian	82	84	81	81
Read Ruleg	81	82	84	78

Heat Unit

	Total	level 1	level 2	level 3
Skinnerian	75	81	71	78
Ruleg	71	76	69	69
Read Skinnerian	65	73	65	61
Read Ruleg	66	76	63	63

Because of the general superiority of the light unit, subsequent analyses consider the light and heat units separately.

Evaluation of the Four Programed Versions

2. Do the four program versions influence science achievement?

The relationship between the four program versions and science achievement was analyzed controlling intelligence and sex. The following statements summarize the findings presented in TABLE IX, Appendix C.

A. The program versions have a significant influence on all levels of science achievement for the light unit and at level 3 for the heat unit. The higher mean achievement favors the developmental presentations (Skinner and Ruleg types) over the summary versions.

B. The influence of intelligence (program and sex controlled) is significant at all achievement levels for both units.

C. Deletion of the sex variable indicates a significant influence at level 3 achievement for the heat unit only. The mean achievement favors the boys. TABLE II presents the descriptive data referred to in the analysis.

TABLE II

MEAN SCIENCE ACHIEVEMENT PRESENTED BY UNIT, SEX, PROGRAM AND ACHIEVEMENT LEVEL

Light Unit

	Boys							
	T	1	2	3	T	1	2	3
Skinnerian	97	99	96	96	92	97	93	88
Ruleg	90	85	91	92	92	96	92	89
Read Skinnerian	82	80	81	83	82	87	81	80
Read Ruleg	80	82	82	78	82	80	88	78

Heat Unit

	Boys				Girls			
Skinnerian	80	88	75	84	71	75	68	71
Ruleg	68	64	65	71	72	81	71	69
Read Skinnerian	66	73	63	65	65	74	66	59
Read Ruleg	71	79	68	68	59	70	55	56

T = total achievement
1 = level 1 - knowledge
2 = level 2 - example and application
3 = level 3 - relationship

(TABLE II, cont.)

HEAT

	IQ	Error Rate
Skinnerian	111	8.14
Ruleg	109	23.4
Read Skinnerian	110	- -
Read Ruleg	111	- -

LIGHT

Skinnerian	121	6.83
Ruleg	109	14.75
Read Skinnerian	112	- -
Read Ruleg	109	- -

HEAT

		IQ	Error Rate
Skinnerian	Boys	112	7.5
	Girls	110	9.0
Ruleg	Boys	106	31.0
	Girls	111	16.2
Read Skinnerian	Boys	107	- -
	Girls	112	- -
Read Ruleg	Boys	107	- -
	Girls	115	- -

(TABLE II - Cont.) LIGHT

		IQ	Error Rate
Skinnerian	Boys	125	5.33
	Girls	118	8.33
Ruleg	Boys	105	21.0
	Girls	113	8.5
Read Skinnerian	Boys	110	- -
	Girls	113	- -
Read Ruleg	Boys	108	- -
	Girls	109	- -

3. How do learner characteristics influence achievement levels for each of the programed versions treated separately?

The relationship between intelligence and sex with achievement levels for each of the four program versions is presented in TABLES X, XI, Appendix D. The findings are as follows:

A. Intelligence influences the science achievement at all levels for the Skinner type program. This relationship is also evidenced in the Read Skinner approach.

B. Sex is a significant variable (level 3) for the Ruleg version. Intelligence is not a significant predictor variable for this method. Rather, the previous analysis suggested error rate as the critical variable.

C. The textual versions indicate no significant relationship between sex and achievement levels.

A summary of findings indicates: (1) Developmental versions (Ruleg and Skinner) are generally superior to textual approaches. The finding holds for all levels of the light unit and for level 3 of the heat unit; (2) Intelligence is a significant variable for the Skinnerian presentation and for all achievement levels (when error rate is not controlled). Sex appears as significant at level 3; (3) Program quality is crucial in determining program differences and identifying related learner characteristics.

Skinner vs. Ruleg

4. What are differences between the two developmental (Skinner vs. Ruleg) programed versions?

An analysis of the two programed versions included the treatment effects (X_5-X_6), unit differences (X_9-X_{10}), intelligence (X_{11}), sex (X_{12}-X_{13}) and error rate (X_{14}) as predictor variables of the achievement levels. The analysis revealed the following instances of a significant influence (Appendix E, TABLE XII):

A. No differences were found between the two programed versions.

B. Unit differences favoring the light program were significant at all achievement levels.

C. Intelligence was significant at total, 1, and 2 achievement levels, did not represent a significant effect at the highest achievement level (3).

D. Sex and error rate were significant variables at level 3.

In summary, although TABLES I and II show a greater mean achievement associated with the Skinnerian version, this treatment was not found to significantly differ from the Ruleg version when intelligence, sex, unit differences and error rate are controlled.

As one would expect from the previous analysis of the four program versions, the light unit is generally superior at each achievement level. At level 3, intelligence is no longer a significant influence. Instead sex and error rate are significant predictor variables at this level.

5. What are the effects related to the two programed versions, when heat and light units are analyzed separately?

The predictor variables are defined as intelligence, sex, error rate, and program version. The statements below are summarized from TABLES XIII and XIV, Appendix F.

A. The significant predictor variables-light unit-are: (1) error rate significantly influences achievement level 1 and total; (2) I.Q. influences level 2; (3) no variable influences level 3.

B. The significant predictor variables-heat unit-are: (1) intelligence influences achievement levels 1 and 2 (and total); (2) no variable significantly influences at level 3.

In summary, a comparison of the two developmental program versions indicates no significantly greater achievement related to the Skinner-type, although the general mean tendency favors this presentation. The findings suggest that for a program of lesser effectiveness (heat), intelligence has a relatively greater influence on achievement than for a unit which results in greater student achievement (light). Where intelligence is not observed to be a significant variable, error rate and/or sex appear as significant variables in a more effective program.

The relationship between the predictor variables (program version, intelligence, sex, and error rate) and levels of achievement is lowest at level 3 (R^2=.29, heat unit; R^2=.29, light unit). TABLES XIII and XIV give values of R^2 at all levels. Because of the relatively low R^2, the influence of achievement levels was observed by including achievement levels 1 and 2 as predictors of achievement level 3. The regression analysis is presented in TABLE XV, Appendix G. It can be observed from TABLE XV that the value of R^2 moves from .29 to .65 (heat unit) and to .36 (light unit) when achievement levels 1 and 2 are added as predictor variables. The heat unit is influenced to a greater extent by previous achievement levels, where level 1 is a significant predictor variable.

II. AUTOMATED READABILITY ANALYSIS

The variables of the revised version of the readability formula (MODEL II) are presented below.

Category I: Frame Characteristics: Step Size, Vocabulary Difficulty.

X_1: Average number of paragraphs per frame per sample.

X_2: Average number of sentences per paragraph per sample.

X_3: Average number of words per sentence per sample.

X_4: Average number of letters per word per sample.

X_5: Average number of words per sample which were outside a standard text, i.e. Thorndike's list of 6,000 words. This is a measure of difficult words. A dictionary of any kind can be generated to determine the frequency and difficulty of a word.

Category II: Response Characteristics: Overt and Covert Responses, Multiple Choice and Constructed Responses, Response Relevancy.

X_7: Per cent of frames that are response frames per sample.

X_8: Per cent of frames with math and scientific terms among alternative responses per sample.

X_9: Per cent of frames with word in frame identical to response alternative.

X_{10}: Per cent of frames with yes-no or true-false response alternative.

X_{11}: Average number of frames in which response is placed within frame (as opposed to last word).

X_{12}: Per cent of frames with one word or phrase (1-3) as response alternative.

Category III: Content Presentation, Organization, and Overlap or Repetition

Density of Mathematical and Scientific Terms

X_{13}: Average number of mathematical and scientific words (terms) per sample.

X_{14}: Average number of letters per technical word.

X_{15}: % of frames in which the same technical term appears more than once.

X_{16}: Average number of frames in which the same technical word appears consecutively.

X_{17}: Average number of consecutive instances of technical word overlap.

Category IV: Sentence Structure or Syntax (Average number of sentences containing the following kinds of words)

X_{18}: Integrators: this, that, it

X_{19}: Signals: because, but, although, as, since, when, then, next, consequently, however, either

X_{20}: Comparative: than

X_{21}: Average number of words per sentence, X_{18} sentence type

X_{22}: Average number of words per sentence, X_{19} and X_{20}

X_{23}: Average number of technical words per sentence, X_{18}

X_{24}: Average number of technical words per sentence, X_{19} and X_{20}

X_{25}: Science unit

Y_1: The criterion variable: average number of errors per sample.

Example of Model II

As an example of Model II consider the following data which include the first two frames sampled from 195 frames and 45 pages of a computer-based program system units (Skinnerian and linear) on light.

EXAMPLE MODEL II

Data - - - - - - - - (page)

1. This is the story of Rocky. Rocky was a little boy who lived many, many years ago. He lived with his family in a cave. Rocky could not play after the sun set in the evening because there was no light. The sun gave him light as we have sunlight today. The sun is one source of our ______________.

a. sound b. music c. light d. water

2. We also get light at night from the stars. The stars are another source of __________.

a. sound b. heat c. music d. light

The automated variable determination for this sample range is:

AUTOMATED VARIABLE DETERMINATION

Paragraphs Per Frame	1.00
Sentences Per Paragraph	4.00
Words Per Sentence	9.13
Letters Per Word	3.88
Percent Words Not in Suds Dictionary	14.81
Frames in the Sample	2.00
Percent Response Frames	100.00
Percent Frames with Related Terminology	100.00
Percent Frames With Word(s) Identical to Resp. Alternative	50.00

Percent Frames With Boolean Resp. Alternative	0.00
Percent Response Frames, Response Not Last	0.00
Percent Frames With Word/Phrase Response Alternative(s)	100.00
Percent Related Terms	23.46
Letters Per Related Term	4.21
Percent Frames With Multiple Occurrences of Related Terms	50.00
Cases of Framewise Overlap	2.00
Cases of Consecutive Overlap Series	2.00
Percent Integration Sentences	12.50
Percent Signal Sentences	25.00
Percent Comparator Sentences	0.00
Words Per Integrator Sentence	6.00
Words Per Signal/Comparator Sentence	13.00
Related Words Per Integrator Sentence	1.00
Related Words Per Signal/Comparator Sentence	2.00

The regression equation which was established by using average student error rates and the 25 variables automatically as independent variables (on samples of 2 to 3 frames) and doing this for the entire light unit as follows:

$$
\begin{aligned}
Y_t = {} & 0.00X_1 + 0.53634252X_2 + 0.42380359X_3 + 0.24834082X_4 \\
& -0.06597135X_5 + 0.25568011X_6 \\
& =0.05417647X_7 + 0.16048602X_8 - 0.12390994X_9 + 0.08214095X_{10} \\
& +0.16147853X_{11} + 0.08054411X_{12} \\
& =-0.14198652X_{13} - 0.32043226X_{14} - 0.01439624X_{15} \\
& - 0.13903314X_{16} + 0.17541607X_{17} \\
& =0.11554272X_{18} +0.28266357X_{19} -0.13069124X_{20} \\
& - 0.19389049X_{21} - 0.29775394X_{22} - 0.15400293X_{23} \\
& + 0.32268684X_{24}
\end{aligned}
$$

In this analysis about 20,000 words and 45 pages of text were analyzed in seconds. The (regression) equation related the independent variables to the criterion variable (error rate) with a multiple correlation coefficient ($R = .84$), as high as or higher than any reported in the literature where less data and more laborious non-automated techniques have been used. This equation accounts for 70% of all the variability among individuals (obtained by squaring the multiple correlation coefficient ($.84^2 = .70$) error rates. This figure is 220% better than our original prototype, Model I, ($R = .573$, ($.573)^2$ $= .32$) $\frac{.70}{.32} = 2.2$) and yields better results than attempts to use programing variables such as overt, covert, step size, etc., which have not given any clear-cut predictability or reliability and whose results have been inconclusive. As is seen by the magnitude of the standard regression weights in our (above) equation, all of the four categories of variables are represented and important; three of these categories introduce variables synthesized from 50 or more learning studies which have never before been used in readability work.

Application of Readability Analysis to Skinnerian and Ruleg Programs

The readability analysis was applied to the Skinnerian and Ruleg programs, heat unit. The automated text tallies are given in TABLES XVI and XVII, Appendix H.

The listing suggests comparability between the two programs in step size and general vocabulary difficulty. As would be expected, the Skinner version contains more frames (288) than does the Ruleg program (155).

Both programs have a similar number of response frames, although the Skinnerian version contains about 10 per cent more frames with technical terminology as a response alternative. This count supports the greater emphasis placed on discrimination in the Skinner-type program. However, the lesser percent of frames with words in frame identical to the response alternative found in the Skinner program may not be consistent with the greater number of prompts usually considered necessary to achieve discrimination in a Skinner-type program.

The content presentation variables reveal comparability between the versions in technical vocabulary. However, the Skinner program contains a greater percentage of multiple occurrences of technical terminology and a larger number of cases of overlap. These results are consistent with the Skinner-principle of shaping behavior.

The listing of the syntax variables indicate that the percent of signal and comparative sentences is greater for the Ruleg program. In addition, the number of technical words in the integrator, signal and comparative sentence structures is relatively greater in the Ruleg program. These data counts suggest the greater use of a complex sentence structure may be involved in a Ruleg program which emphasizes the stating of rules and applications.

The standard weights associated with the 25 readability variables, Ruleg and Skinner programs, are presented in TABLES XVIII, Appendix I.

The total error rate was lower for the Skinner program (8.14) than for the Ruleg version (23.4); hence, a relatively lower R^2 is observed for the Skinner program. The contribution of variables, 1, 3, 4, frame characteristics, the number of integrator sentences, variable 18, and number of words contained in this sentence type, variable 21, to error rate is consistent with the Skinnerian principles of small step size and shaping behavior. It is quite possible that the use of "this, that, it" (integrator sentences) created ambiguities, particularly in the Skinner approach.

In contrast, the number of signal and comparative sentences and the number of words and technical terms contained in these sentence types is one major source of learning difficulty in the Ruleg program. A second source of difficulty indicated by the standard weights is the need for more steps and overlapping (variables 17 and 15). General vocabulary difficulty and technical word length difficulty (variables 5 and 14) substantiate the suggested need for more frames and greater overlap in the introduction of concepts, as well as in the presentation of relationships in signal and comparative sentence types. Reduction of the complexity of sentence structure (within the constraints of the Ruleg programing technique) is also suggested by the analysis.

III. BRANCHING CONDITIONS

The branch effectiveness was evaluated by a multivariate analysis ( ). The three branching conditions are defined as:

Adaptation 1. Knowledge of - Lexical Component

Adaptation 2. Comprehension of - Structural Component/ Sentence

Adaptation 3. Comprehension of - Structural Component/ Topical

The three treatments were (1) no branching condition, (2) comprehension branches - adaptation 2 or 3, (3) knowledge and comprehension - adaptation 1 in combination with either adaptation 2 or 3. Predictor variables were defined as:

$X_2 - X_4$ = achievement at levels 1, 2, 3, respectively

X_5 = error rate

X_9 = time (in minutes)

X_{10} = intelligence

$X_{11} - X_{12}$ = sex

The criterion variable was defined as science achievement (% of current items on subtests):

Y_1 = total achievement

Y_2 = achievement at Level 1 - knowledge

Y_3 = achievement at Level 2 - example and application

Y_4 = achievement at Level 3 - relationship

The results of the multivariate analyses are summarized in TABLE XIX, Appendix J. Time, intelligence and sex are defined as control variables at all achievement levels. In addition, levels of achievement and error rate are included as controls when total achievement is the criterion variable. The findings are as follows:

1. Branching adaptations significantly influence science achievement at all achievement levels.

2. Branching adaptations contribute to total science achievement beyond that accounted for by levels of achievement (knowledge, application, relationship) and error rate in combination with knowledge attainment.

TABLE III presents the mean science achievement, error rate, time (in minutes), and intelligence for each of the three branching treatments.

TABLE III

Mean Science Achievement, Error Rate, Time, and Intelligence for the Three Branching Treatments

	Treatment 1 No Branch	Treatment 2 Comprehension Branches	Treatment 3 Knowledge & Comprehension Branches
Total Achievement	70	77	84
Level 1 - Knowledge	82	89	93
Level 2 - Application	67	71	80
Level 3 - Relationship	63	74	81
Error rate	.21	.14	.10
Time	285	319	273
Intelligence	111	106	115

It can be observed from TABLE III that the descriptive data are consistent with the analysis and with the branching rationale. Although direct comparisons are not possible because of differences in mean intelligence (intelligence, sex and time were controlled in the analysis), total achievement increases from the no branching condition to the presentation of both knowledge and comprehension branches. Comprehension (Levels 2 and 3) is improved with the introduction of comprehension branches, and knowledge attainment (Level 1) is highest when the knowledge branching condition is introduced under Treatment 3. Error rate likewise drops with the addition of branching conditions.

In summary, the branching rationale holds promise as an effective means to remediate the reading difficulty of programed texts. With the inclusion of branches, science achievement is improved, error rate drops, and the relationship between intelligence and achievement is reduced. That is, the correlations between intelligence and total achievement are r = .64, r = .52, r = .48 for treatments 1, 2, 3, respectively.

Application to Readability Analysis

The content of the heat unit into which the branching versions were introduced was analyzed using the automated readability analysis. The standard weights associated with the readability variables are presented in Appendix K, TABLE XX. The R^2 between the contextual variables and error rate equals .77.

In this analysis, the frame number was included to ascertain the influence of sequencing on error rate, and to determine if the assumption of a logical presentation was met. The variable, frame number, is the primary contributer to error rate; i.e., students progress through the unit with an increasing number of errors. A positive relationship is observed between frame number and number of technical terms (r = .18), between frame number and technical word overlap (r = .47), and between frame number and technical words included in integrator and signal/comparative sentences (r = .26; r = .33).

The greater attainment of knowledge relative to the comprehension achievement levels and to the no branching condition (TABLE III) is evidenced by the insignificant contribution of technical terminology to error rate vs. the significant contribution of technical words contained in signal/comparative sentence structures. Further study with a larger sample size would allow one to ascertain the extent to which comprehension branches reduce the reading difficulty of sentence types, integrator, signal/comparatives. It is possible that the adaptation, comprehension-sentence structure is more appropriate for the signal/comparative sentence types and that the comprehension adaptation-topical, is more effective in reducing the ambiguity previously observed with integrator sentence structure.

IV. FACTOR ANALYSIS OF READABILITY MODEL

To facilitate interpretation of the variables in the model, a principle components Factor analysis of the preceeding data (Model presented in TABLE XVIII Appendix I was completed with variance rotation(43) and yielded four factors. These factors and their loadings are presented in TABLE IV. Only those 15 variables which gave principal loadings on one of the four factors are included in the table.

TABLE IV

Variable No.*	Factor I	Factor II	Factor III	Factor IV
16	*0.8334	0.0645	0.0018	-0.1602
13	*0.7963	-0.0913	0.0348	-0.2367
17	*0.7907	0.1844	0.1883	-0.0729
8	*0.5833	-0.1086	-0.1337	0.2304
3	-0.0315	*0.7949	0.4070	-0.1340
22	-0.2699	*0.6990	-0.1796	-0.3339
24	0.1809	*0.6923	-0.1329	-0.0560
23	0.0213	*0.6700	-0.0345	0.1435
21	-0.3888	*0.6556	-0.0887	-0.2006
2	0.2832	0.0098	*0.7528	-0.1040
6	0.1068	-0.2570	*-0.7198	-0.3756
7	0.0066	0.1527	*-0.6951	0.1406
12	0.1269	0.1455	*-0.6450	-0.1623
4	-0.1244	-0.0892	0.0581	*0.7610
5	-0.3021	-0.2761	-0.1973	*0.7321

*See Section II, Automated Readability Analysis for variable identification.

Inspection of these loadings indicates that Factor I consists primarily of variables from category 3, content presentation and organization; Factor II from category 4, sentence structure or syntax; Factor III from category 2, response characteristics, and Factor IV from category 1, frame characteristics. These loadings suggest that the original classification of readability variables was appropriate.

V. SUMMARY OF FINDINGS

1. The developmental presentations, Skinnerian and Ruleg, were generally superior to the textual counterparts at the three achievement levels, knowledge, comprehension, and relationships.

A. The Skinnerian version was found to be generally more effective than the Ruleg presentation. This finding is qualified by the greater error rate associated with the Ruleg version, which may be attributed either to the method per se or to the programers' ability.

B. Intelligence is more closely related to both developmental and textual presentations of the Skinner type.

2. The two units, heat and light, differed in program quality. The light unit was observed to be more effective at all achievement levels. Program quality was observed to be a critical variable in attempting to establish the superiority of a program version and in

identifying significant learner characteristics. Where intelligence was not a significant variable, error rate and sex appeared as significant. In addition, achievement at the lowest conceptual level appeared as significant to the attainment of relationship objectives in the lower quality program.

3. Application of the automated readability analysis to the developmental versions, Skinnerian and Ruleg, indicated comparability between the two programs in step size and general vocabulary difficulty.

A. Greater emphasis on shaping behavior and discrimination was evidenced in the Skinner program by the greater number of frames (Skinner - 288; Ruleg - 155), the greater number of cases of overlap, and about 10 percent more frames with technical terminology as a response alternative. However, a lesser percent of frames with a word in the frame identical to the response alternative may not be considered with the greater number of prompts usually considered necessary to achieve discrimination in a Skinner-type program.

B. A listing of the syntax variables indicated that application of rules was applied to a greater extent in the Ruleg version. This program contained a greater percent of signal and comparative sentences. In addition, ahe number of technical words in the integrator and comparative sentence structures is relatively greater in the Ruleg program. These variables comprised one major source of learning difficulty in the Ruleg program. The automated analysis suggested the need for more frames and greater overlap in the introduction of concepts, as well as in the presentation of relationships in signal and comparative sentence types.

C. The contribution of three variables under frame characteristics and the number of integrator sentences to error rate in the Skinnerian program is consistent with the principles of small step size and shaping behavior. It is quite possible that the use of "this, that, it" (integrator sentence structure) created ambiguities, particularly with the Skinner approach.

4. The automated readability analysis proved successful. In Model I seventeen independent variables were automatically determined and in Model II the number of independent variables was extended to twenty-five (See Appendix L fσr prototype of computer program).

A. On samples of 2 to 3 frames, 45 pages of text, the 25 independent variables were related to error rate with R = .84. Thus, the automated analysis accounts for 70 percent of all of the variability among individuals' error rates.

B. A factor analysis of the readability analysis validates the four categories of independent variables: frame characteristics, response variables, content presentation and organization, and the syntax classification.

5. The branching rationale, (1) Knowledge of - Lexical Component, (2) Comprehension of - Structural Component/Sentence, (3) Comprehension of - Structural Component/Topical, holds promise as an effective means to individualize the program sequence.

A. When branching conditions were classified into treatment groups, (1) no branching condition, (2) comprehension branches, and (3) knowledge and comprehension branches, the branching adaptations significantly influenced science achievement at all achievement levels. The mean achievement favored groups 3, 2, and 1, respectively.

B. The branching adaptations contributed to total science achievement beyond that accounted for by levels of achievement, error rate, time, intelligence, and sex.

C. The branching program met the assumptions of good sequential development. Significant and positive relationships were observed between frame number and error rate, between frame number and number of technical terms, and between frame number and technical word overlap.

D. The application of the automated readability analysis to the branching program in which the individual contribution of the independent variables to error rate could be observed was consistent with the mean comparisons between treatment groups.

Chapter IV

CONCLUSIONS AND RECOMMENDATIONS

The major accomplishments of the study are summarized below.

Four Program Versions

The evaluation of the four program versions, (1) Developmental - Skinner-type, (2) Developmental - Ruleg, (3) textual counterpart of the Skinner-type, and (4) textual counterpart of the Ruleg presentation, suggested that the developmental presentations were more effective at the three achievement levels (knowledge, comprehension, relationships) than the textual presentations. This finding was was evidenced for all intelligence levels.

Program quality was critical in the evaluation of the four versions. Differences in error rate between the two units, heat and light, were accompanied by a change in the relationship of intelligence, error rate, sex, and lower achievement levels to the criterion, science achievement. The error rate of the Ruleg presentation was relatively higher than that of the Skinner version. Although the mean achievement favored the Skinnerian approach, a comparison of the two developmental presentations must be qualified to allow for differences in a programmer's writing style before the superiority of any one method can be established. The application of the automated analysis indicated that the syntax category of independent readability variables was crucial to the success of both the Skinner and Ruleg programs. Comparative and signal sentences were more frequent in the Ruleg presentation, and contributed to learning difficulty for this version, while integrator sentences (this, that, it) were related to error rate in the Skinner approach.

The evaluation of the four program versions recommends a consideration of learner and task variables. However, the findings suggest that before comparisons can be meaningful and generalizable, the program structure must be objectively defined and the influence of contextual variables accounted for. Such a contextual analysis of programed materials appears even more important, since the findings of this study favor the development presentations over the textual versions. The use of the computer for management, as opposed to instruction, can only be given qualified support.

Automated Readability Model

Several features of the automated readability analysis offer specific advantages for the use of this model in the management of programed materials development. One outstanding feature of this model is its flexibility. At its present stage of development 25 variables are used to determine reading difficulty. In principle an unlimited number of variables can be generated. The automated system allows thoroughness and completeness in using entire texts, a marked contrast to past readability formulas.

Another important feature of the model is the ease with which it can be used. Natural language inputs from a variety of sources such as magnetic tapes, data cards and disc storage can be directly used. Program translations that are costly and time-consuming are unnecessary.

Past readability formulas were ready-made for use by laymen and other non-computationally oriented persons, resulting in restrictions on the clerical effort and computational skill needed to apply the formula. Samples of textual materials rather than entire texts were used. These samples were often in adequate and not representative of the materials they were taken from. Both limitations were necessary because man, not a machine, was doing the work.

The automated feature and related analysis offer specific advantages to the production of programed materials (1) either directly, in the writing, revision and evaluation of materials; and (2) or through experimentation, in program definition and evaluation of the relative influence of methods on program structure. Applications of the automated model to the management of materials development are presented below.

1. The automated procedures and regression analysis is adapted to and provides an objective measure of the reading difficulty of programed materials. The procedures developed by the study are applicable to a general analysis of self-instructional materials and are specifically adapted to an evaluation of upper elementary school science. Independent variables automatically determined by the computer program are:

Category I: Frame Characteristics. Six variables which measure paragraph, sentence and word length, vocabulary difficulty and number of frames per sample.

Category II: Response Characteristics. Six variables which describe the number of response frames, the nature and relevance of the response.

Category III: Content Presentation and Organization. Five variables which measure density of mathematical and scientific terms, overlap and repetition.

Category IV: Sentence Structure or Syntax. Seven variables which identify three sentence types, the average number of words and technical words per sentence type. The remaining independent variable identifies the science unit.

Criterion Variable. Average number of wrrors per sample.

2. The readability formula predicts student error rate, thereby providing a measure of the effectiveness of the materials without involving the expense and time in field or laboratory testing. In an analysis of 45 pages of text taken from an upper elementary science

unit, the regression equation related the independent variables to the criterion variable (error rate) with a multiple correlation coefficient (R = .84), as high as or higher than any reported in the literature where less data and more laborious non-automated techniques have been used. Application of the automated analysis to two programed units contained in the BSCS Special materials accounted for 86 and 84 percent of the variability among individuals' error rates (59).

3. The automated feature makes possible (or feasible) the analysis of the entire text at a substantially lower cost and time expenditure than would be required of most manually conducted samples. An analysis of about 20,000 words was completed in seconds.

4. Revision procedures are more efficient: (a) the time lag created by field testing and manual counts is reduced; (b) the analysis of the entire text allows the identification of differences among the writing practices of programers, the differences among units, hierarchies, or sequential organization; (c) the summary data and analysis suggest revisions specific to the program context, hence avoiding the trial and error often associated with those program modifications, which are unrelated to student performance or relevant contextual variables.

5. The automatic count and listing and regression analysis objectively defines and relates significant frame, response content presentation, organization, and syntax variables to error rate, thus providing a comprehensive definition of program structure. Contextual differences between Skinnerian and Ruleg programs were identified, and sources of learning difficulty were isolated after the introduction of three branching conditions. The automated analysis makes possible the determination of why a branching condition is successful, and objectively describes similarities and differences between programing techniques.

6. The independent variables were synthesized from an analysis of more than 200 previous studies in readability and an analysis of over 50 studies of programed learning. A principle components factor analysis was completed with varimax rotation and yielded four factors. The loadings suggest that the fourfold classification of independent variables was appropriate.

The branching rationale can be described as a threefold hierarchy, with each level or branching condition more difficult, complex and abstract than the previouslevel. The first level deals with technical terminology; students at this level acquire a knowledge of concepts. At the second level an analysis is made of sentence length and structure. A topical presentation or preview describes the third branching condition. These three branch conditions can be summarized as (1) Knowledge of - Lexical Component, (2) Comprehension of - Structural Component/Sentence, and (3) Comprehension of - Structural Component/Topical.

Initial evaluation of the three branching conditions indicated that the three program adaptations decreased the level of reading difficulty so that a student understood the materials that he previously found perplexing. The findings suggest that the branching rationale will enable one to determine when readability increases or decreases for students of varying ability and knowledge.

In summary, the automated feature and related analysis appear to offer specific advantages for the analysis and production of self-instructional materials in three principal ways: first, directly, in the development of materials by managing their writing, revision, and evaluation; second, to develop and analyze diverse programs; third, managing instruction by means of branching conditions which take into account variation in learner characteristics.

SUMMARY

Statement of Purpose and Objectives

Despite technological advances, the production of self-instructional materials remains costly and inefficient. The expenditures of time and money invested in testing and analysis has not resulted in a set of principles of programed instruction to guide in the writing and revision of programed materials. Nor has experimentation in programed instruction agreed on the influence of a programing variable or a rationale to select and adapt a given strategy to the programed context. The research reported in this project focuses on the effective development, evaluation, and individualization of programed materials.

Phase I

Efforts to develop successful programing methods have led to the wide variation in the application of the principles of learning to materials development. However, program assessment studies have not generated a set of principles to guide in the selection of a programing technique. Learner characteristics and task variables are frequantly not considered in identifying the appropriate programing technique. Phase I of the research activity responds to this need by an evaluation of four programing methods which accounts for individual differences and variation in conceptual attainment.

The study did not favor any particular programing method, but served as a pilot approach by selecting four programing methods from among the many techniques, and by relating the effectiveness of the method of presentation to learner characteristics, program quality and to the conceptual level of the behavioral objective. The four methods selected were (1) developmental - Skinnerian, (2) developmental - RULEG, (3) textual counterpart of the Skinner type, and (4) textual counterpart of the RULEG presentation.

Phase II

Research studies tend to agree that reading difficulty is an important criterion for selecting textual materials; and, as such, textbook selection is an exceedingly important and difficult task. Reading difficulty is even more crucial to the students' success in using programed materials. Despite the apparent relationship between reading difficulty and self-instructional materials, readability has largely been ignored in the study of programed learning. The significance of the reading factor and the absence of a formula adapted to the programed approach prompted the research activity of Phase II of the reported research. The major objective of this phase of activity was the development of an automated analysis to manage programed materials development which includes a synthesis of both programing and readability variables.

Phase II of the study identifies 25 independent readability variables which are descriptive of frame characteristics, response variables, content presentation and organization, and syntax variables. The automated procedures sort, locate, and accumulate a count and listing of the independent variables from the context of the programed materials. After a printout of the variable counts and word listings is obtained, the independent variables are related to student error rate (validated against student ability and achievement measures). The readability formula is described by an equation of the best predictors of error rate. Thus, descriptive data are presented for all variables, those readability variables significantly related to student performance are identified, and the nature of the relationship is established.

Phase III

The definition and evaluation of three remedial branching conditions derived from the automated readability model is the focus of Phase III. The branching rationale can be described as a threefold hierarchy, with each level or branching condition more difficult, complex and abstract than the previous level. The first level deals with technical terminology; students at this level acquire a knowledge of concepts. At the second level an analysis is made of sentence length and structure. A topical presentation or preview describes the third branching condition.

The objectives of each phase of research activity are outlined below.

Phase I. The evaluation of the four program versions (Skinner-type, Ruleg, and the textual counterparts of each developmental presentation) was carried out to identify the technique(s) most effective for the attainment of science achievement at three levels, knowledge, application, and relationships. The analysis focused on the following two objectives:

1. What is the relationship between the four programing versions and the science achievement of fourth and fifth grade students?

2. What are the learning conditions which describe the relative success of each of the four presentations?

Learning conditions are defined as learner characteristics (intelligence and sex) and program quality (error rate and science achievement).

Phase II. The following objectives were specified in the development and implementation of the automated readability analysis.

1. Abstract and classify from readability and programed learning studies those independent contextual variables to be automatically determined by the readability analysis. Validate the independent variable classifications.

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2. Develop a computer program which sorts, locates, and accumulates a count and listing of the independent variables from the context of the programed materials.

3. Implement the readability analysis by relating the independent variables to error rate. The readability formula is described by an equation of the best predictors of error rate.

4. Apply the automated readability analysis to the Skinnerian and Ruleg programs (Phase I) and to the programed unit which incorporates the three branch conditions (Phase III) in order to objectively define the program structure and to distinguish similarities and differences between programing techniques. Determine if the assumptions of sequencing are met.

Phase III. A fully developed readability model requires individual adaptations which decrease the level of reading difficulty. The objectives outlined under this phase of research activity are as follows:

1. Derive a branch rationale from the automated analysis.

2. Evaluate the branching conditions: (1) Knowledge of - Lexical Component, (2) Comprehension of - Structural Component/Sentence, (3) Comprehension of - Structural Component/Topical.

3. Include in the evaluation control for intelligence, sex, time, error rate and science achievement levels (knowledge, application, relationships).

Procedures

Phase I. Two programed science units, heat and light, were each rewritten using the four presentations:

1. Developmental - Skinner-type
2. Developmental - Ruleg
3. Summary - textual counterpart of (1)
4. Summary - textual counterpart of (2)

The programed units were adapted to an IBM 1460 Computer System. The developmental branches required the student to respond to each frame; students assigned to the summary treatments read the same materials written in textbook form. All students received the same subtesting series and remedial branches on the computer, and all were engaged in the individual performance of simple science experiments.

Fourth and fifth grade students, matched by ability and grade level, were randomly assigned to the four treatments (n=56, heat unit; n=48, light unit). Student characteristics were measured by the Lorge-Thorndike Intelligence Test and the sex of the student was recorded. Each subtest item was classified as follows:

Level 1 - concept/terminology (Level 1, Bloom)
Level 2 - example and application (Levels 2 and 3, Bloom)
Level 3 - relationship (Levels 4 and 5, Bloom)

A multiple regression technique was used to evaluate the four programing versions.

Phase II. The procedures followed the objectives outlined above. A flexible multi-variable--presently twenty-five--computerized approach to determine the readability and to guide in the writing and revision of self-instructional materials was developed and implemented by the Bureau of Educational Research, University of Virginia.

Phase III. Three branching conditions were incorporated into a programed heat unit, adapted to an IBM 1460 computer:

1. Knowledge of - Lexical Component
2. Comprehension of - Structural Component/Sentence
3. Comprehension of - Structural Component/Topical

Forty-three fourth grade students were randomly assigned to three treatments: (1) no branching conditions, (2) a comprehension branch, (3) knowledge branch in combination with a comprehension branch. A multivariate analysis was used to evaluate the three branch conditions, where levels of achievement, error rate, time, intelligence, sex, and experimental treatments were defined as predictor variables, and science achievement at three conceptual levels, defined as the criterion.

Findings and Conclusions

The evaluation of the four program versions, (1) Developmental - Sinner-type, (2) Developmental - Ruleg, (3) textual counterpart of the Skinner-type, and (4) textual counterpart of the Ruleg presentation suggested that the developmental presentations were more effective at the three achievement levels (knowledge, comprehension, relationships) than the textual presentations. This finding was evidenced for all intelligence levels.

Program quality was critical in the evaluation of the four versions. Differences in error rate between the two units, heat and light, were accompanied by a change in the relationship of intelligence, error rate, sex and lower achievement levels to the criterion, science achievement. The error rate of the Ruleg presentation was relatively higher than that of the Skinner version. Although the mean achievement favored the Skinnerian approach, a comparison of the two developmental presentations must be qualified to allow for differences in a programmer's writing style before the superiority of any one method can be established. The application of the automated analysis indicated that the syntax category of independent readability variables was crucial to the success of both the Skinner and Ruleg programs. Comparative and signal sentences structures were more frequent in the Ruleg presentation, and contributed to learning difficulty for this verion, while integrator sentences (this, that, it) were related to error rate in the Skinner approach.

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4. Revision procedures are more efficient: (a) the time lag created by field testing and manual counts is reduced; (b) the analysis of the entire text allows the identification of differences among the writing practices of programers, the differences among

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units, hierarahies, or sequential organization; (c) the summary data and analysis suggest revisions specific to the program context, hence avoiding the trial and error often associated with those program modifications which are unrelated to student performance or relevant contextual variables.

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2. The branching adaptations contributed to total science achievement beyond that account for by levels of achievement, error rate, time, intelligence, and sex. The program met the assumption of good sequential development. Significant and positive relationships were observed between frame number and error rate, between frame number and number of technical terms, and between frame number and technical word overlap.

3. The application of the automated readability analysis to the branching program indicated that the three program adaptations decreased the level of reading difficulty.

In summary, the automated feature and related analysis appear to offer specific advantages for the analysis and production of self-instructional materials in three principal ways: first, directly in the development of materials by managing their writing, revision, and evaluation; second to develop and analyze diverse programs; third, managing instruction by means of branching conditions which take into account variation in learner characteristics.

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APPENDIX A

Key to Variables Analyzed by Multivariate Analyzed in the Evaluation of the Four Programing Versions

Key to Variables Analyzed by Multivariate Analysis

Variable Number	Variable
1	Total Score
2	Level 1 Score
3	Level 2 Score
4	Level 3 Score
5	Skinnerian Program
6	Ruleg
7	Read Skinnerian
8	Read Ruleg
9	Heat Unit
10	Light Unit
11	IQ
12	Male
13	Female
14	Error Rate
15	Unit Vector

APPENDIX B

TABLE V

Analysis of the Effects of Achievement Levels Attributed
to Science Unit Differences - Developmental Versions

TABLE VI

Analysis of the Effects on Achievement Levels Attributed
to Science Unit and Error Rate Differences-Skinnerian Program

TABLE VII

Analysis of the Effects on Achievement Levels Attributed
to Science Unit and Error Rate Differences-Ruleg Program

TABLE VIII

Analysis of the Effects on Achievement Levels Attributed
to Science Unit and Error Rate Differences - Read Skinnerian
and Ruleg Versions

TABLE V

ANALYSIS OF THE EFFECTS ON ACHIEVEMENT LEVELS ATTRIBUTED TO SCIENCE UNIT DIFFERENCES - DEVELOPMENTAL VERSIONS

	Variables						
	Dependent	Independent	RSQ	F-ratio	p	df_1	df_2
FULL MODEL	1	9,10,11,14,	.5978				
RSTR MODEL	1	11,14,15	.3599	28.4	xx*	1	48
FULL MODEL	2	9,10,11,14	.4519				
RSTR MODEL	2	11,14,15	.3506	8.87	xx	1	48
FULL MODEL	3	9,10,11,14	.7335				
RSTR MODEL	3	11,14,15	.4036	59.4	xx	1	48
FULL MODEL	4	9,10,11,14	.4157				
RSTR MODEL	4	11,14,15	.2413	14.32	xx*	1	48

*significant beyond .01 level

TABLE VI

ANALYSIS OF THE EFFECTS ON ACHIEVEMENT LEVELS ATTRIBUTED TO SCIENCE UNIT DIFFERENCES AND ERROR RATE - SKINNERIAN PROGRAM

	Variables						
	Dependent	Independent	RSQ	F-ratio	p	df_1	df_2
Full Model	1	9,10,11,12,13,14	.5659				
Rstr Model	1	11,12,13,14	.3911	8.45	xx	1	21
Rstr Model	1	9,10,11,12,13	.5440	1.0582	.32	1	21
Full Model	2	9,10,11,12,13,14	.4352				
Rstr Model	2	11,12,13,14	.3683	2.49	.12	1	21
Rstr Model	2	9,10,11,12,13	.3539	3.02	.09	1	21
Full Model	3	9,10,11,12,13,14					
Rstr Model	3	11,12,13,14	.4540	38.4	xx	1	21
Rstr Model	3	9,10,11,12,13	.8068	.004	.95	1	21
Full Model	4	9,10,11,12,13,14	.3796				
Rstr Model	4	11,12,13,14	.2759	3.51	.07	1	21
Rstr Model	4	9,10,11,12,13	.3590	.70	.41	1	21

TABLE VIII

ANALYSIS OF THE EFFECTS ON ACHIEVEMENT LEVELS ATTRIBUTED TO SCIENCE UNIT DIFFERENCES AND ERROR RATE-RULEG VERSION

	Variables						
	Dependent	Independent	RSQ	F-ratio	p	df_1	df_2
Full Model	1	9,10,11,12,13,14	.7258				
Rstr Model	1	11,12,13,14	.5417	14.10	xx	1	21
Rstr Model	1	9,10,11,12,13	.6443	6.24	.02	1	21
Full Model	2	9,10,11,12,13,14	.6801				
Rstr Model	2	11,12,13,14	.6313	3.20	.08	1	21
Rstr Model	2	9,10,11,12,13	.5747	6.92	.01	1	21
Full Model	3	9,10,11,12,13,14	.7087				
Rstr Model	3	11,12,13,14	.4515	18.54	xx	1	21
Rstr Model	3	9,10,11,12,13	.6693	.67	.42	1	21
Full Model	4	9,10,11,12,13,14	.6382				
Rstr Model	4	11,12,13,14	.4675	9.90	xx	1	21
Rstr Model	4	9,10,11,12,13	.5082	7.54	.01	1	21

TABLE VIII

ANALYSIS OF THE EFFECTS ON ACHIEVEMENT LEVELS ATTRIBUTED TO SCIENCE UNIT DIFFERENCES --- READ SKINNERIAN AND READ RULEG VERSIONS

Read Skinnerian

	Variables						
	Dependent	Independent	RSQ	F-ratio	p	df_1	df_2
Full Model	1	9,10,11,12,13	.5892				
Rstr Model	1	11,12,13	.2965	15.67	xx	1	22
Full Model	2	9,10,11,12,13	.4894				
Rstr Model	2	11,12,13	.4099	3.42	.07	1	22
Full Model	3	9,10,11,12,13	.3802				
Rstr Model	3	11,12,13	.0807	10.63	xx	1	22
Full Model	4	9,10,11,12,13	.5382				
Rstr Model	4	11,12,13	.2734	12.61	xx	1	22

Read Ruleg

	Dependent	Independent	RSQ	F-ratio	p	df_1	df_2
Full Model	1	9,10,11,12,13	.2929				
Rstr Model	1	11,12,13	.0768	.72	.02	1	22
Full Model	2	9,10,11,12,13	.3673				
Rstr Model	2	11,12,13	.3261	1.44	.24	1	22
Full Model	3	9,10,11,12,13	.4597				
Rstr Model	3	11,12,13	.0376	17.18	xx	1	22
Full Model	4	9,10,11,12,13	.2568				
Rstr Model	4	11,12,13	.0747	5.39	.03	1	22

APPENDIX C

TABLE IX

The Relationship among the 4 Programs, Intelligence, Sex, and Achievement

TABLE IX

The Relationship among the 4 programs, intelligence, sex and achievement

LIGHT

	Variables Dependent	Independent	RSQ	F-ratio	p	df_1	df_2
FULL MODEL	1	5,6,7,8,11,12,13	.579				
RSTR MODELS							
a) delete IQ	1	5,6,7,8 12,13	.447	13.178	xx	1	42
b) delete sex	1	5,6,7,8,11	.57	0.27	0.8	1	42
c) delete programs	1	11,12,13	.298	9.36	xx	3	42
FULL MODEL	2	5,6,7,8,11,12,13	.4834				
RSTR MODELS							
a) delete IQ	2	5,6,7,8, 12,13	.317	13.52	xx	1	42
b) delete sex	2	5,6,7,8,11	.47	0.77	.5	1	42
c) delete programs	2	11,12,13	.329	4.19	.01	3	42
FULL MODEL	3	5,6,7,8,11,12,13					
RSTR MODELS							
a) delete IQ	3	5,6,7,8, 12,13	13.1	13.1	xx	1	42
b) delete sex	3	5,6,7,8,11	.05	.05	.8	1	42
c) delete programs	3	11,12,13	5.63	5.63	xx	3	42
FULL MODEL	4	5,6,7,8,11,12,13					
RSTR MODELS							
a) delete IQ	4	5,6,7,8, 12,13	5.7	5.7	.02	1	42
b) delete sex	4	5,6,7,8,11	0.9	0.9	.3	1	42
c) delete programs	4	11,12,13	5.32	5.32	xx	3	42

1 = total achievement
2 = level 1
3 = level 2
4 = level 3
5,6,7,8 = programs
11 = intelligence
12,13 = sex

TABLE IX (cont.)

HEAT

	Variables Dependent	Independent	RSQ	F-ratio	p	df_1	df_2
FULL MODEL	1	5,6,7,8,11,12,13	.338				
RSTR MODELS							
a) delete IQ	1	5,6,7,8, 12,13	.095	18.4	xx	1	50
b) delete sex	1	5,6,7,8,11	.28	4.4	.04	1	50
c) delete programs	1	11,12,13	.272	1.66	.18	3	50
FULL MODEL		5,6,7,8,11,12,13	.358				
RSTR MODELS							
a) delete IQ		5,6,7,8, 12,13	.032	25.4	xx	1	50
b) delete sex		5,6,7,8,11,	.336	1.6	.2	1	50
c) delete programs		11,12,13	.338	.516	.67	3	50
FULL MODEL		5,6.7,8,11,12,13	.260				
RSTR MODELS							
a) delete IQ		5,6,7,8, 12,13	.072	12.69	xx	1	50
b) delete sex		5,6,7,8,11	.216	2.96	.09	1	50
c) delete programs		11,12,13	.201	1.33	.28	3	50
FULL MODEL		5,6.7,8,11,12,13	.314				
RSTR MODEL							
a) delete IQ		5,6,7,8, 12,13	.178	9.9	xx	1	50
b) delete sex		5,6,7,8,11,	.231	6.0	.02	1	50
c) delete programs		11,12,13	.197	2.83	.04	3	50

1 = total achievement
2 = level 1
3 = level 2
4 = level 3
5,6,7,8 = programs
11 = intelligence
12,13 = sex

APPENDIX D'

TABLE X

Analysis of the Effects on Achievement Levels Attributed to Intelligence and Sex (Error Rate Controlled) - Skinnerian and Ruleg Programs

TABLE XI

Analysis of the Effects on Achievement Levels Attributed to Intelligence and Sex (Error Rate Controlled) - Read Skinnerian and Read Ruleg Versions

TABLE X

Analysis of the Effects on Achievement Levels Attributed to Intelligence and Sex (Error Rate Controlled) - Skinnerian and Ruleg Programs

	Variables Dependent	Variables Independent	RSQ	F-ratio	p	df_1	df_2
		Skinnerian					
FULL MODEL	1	11,12,13,14	.3911				
RSTR MODEL	1	12,13,14	.0560	12.11	xx	1	22
RSTR MODEL	1	11, 14	.3753	.28	.75	2	22
FULL MODEL	2	11,12,13,14	.3683				
RSTR MODEL	2	12,13,14	.0352	11.6010	xx	1	22
RSTR MODEL	2	11, 14	.3420	.4587	.63	2	22
FULL MODEL	3	11,12,13,14	.4540				
RSTR MODEL	3	12,13,14	.1186	13.5150	xx	1	22
RSTR MODEL	3	11, 14	.4467	.1471	.86	2	22
FULL MODEL	4	11,12,13,14	.2759				
RSTR MODEL	4	12,13,14	.0745	6.1192	.02	1	22
RSTR MODEL	4	11, 14	.2260	.7580	.48	2	22
		Ruleg					
FULL MODEL	1	11,12,13,14	.5417				
RSTR MODEL	1	12,13,14	.5407	.0495	.82	1	22
RSTR MODEL	1	11, 14	.5148	.6464	.53	2	22
FULL MODEL	2	11,12,13,14	.6313				
RSTR MODEL	2	12,13,14	.6288	.1494	.70	1	22
RSTR MODEL	2	11, 14	.6283	.0909	.91	2	22
FULL MODEL	3	11,12,13,14	.4515				
RSTR MODEL	3	12,13,14	.4160	1.4265	.25	1	22
RSTR MODEL	3	11, 14	.4437	.1569	.85	2	22
FULL MODEL	4	11,12,13,14	.4675				
RSTR MODEL	4	12,13,14	.4536	.5750	.46	1	22
RSTR MODEL	4	11, 14	.3604	.3604	2.2129	2	22

TABLE XI

Analysis of the Effects on Achievement Levels Attributed to Intelligence and Sex - Read Skinnerian and Read Ruleg Versions

Read Skinnerian

	Variables						
	Dependent	Independent	RSQ	F-ratio	p	df_1	df_2
FULL MODEL	1	11,12,13	.2965				
RSTR MODEL	1	12,13	.0003	9.6845	xx	1	23
RSTR MODEL	1	11	.2769	.3210	.72	2	23
FULL MODEL	2	11,12,13	.4099				
RSTR MODEL	2	12,13	.0125	15.4924	xx	1	23
RSTR MODEL	2	11	.4089	.0208	.97	2	23
FULL MODEL	3	11,12,13	.0807				
RSTR MODEL	3	12,13	.0013	1.9846	.17	1	23
RSTR MODEL	3	11	.0799	.0095	.99	2	23
FULL MODEL	4	11,12,13	.2734				
RSTR MODEL	4	12,13	.0149	8.1838	xx	1	23
RSTR MODEL	4	11	.2191	.8598	.44	2	23

Read Ruleg

	Dependent	Independent	RSQ	F-ratio	p	df_1	df_2
FULL MODEL	1	11,12,13	.0768				
RSTR MODEL	1	12,13	.0259	1.2676	.27	1	23
RSTR MODEL	1	11	.0362	.5059	.61	2	23
FULL MODEL	2	11,12,13	.3261				
RSTR MODEL	2	12,13	.0353	9.9214	xx	1	23
RSTR MODEL	2	11	.2429	1.4190	.26	2	23
FULL MODEL	3	11,12,13	.0376				
RSTR MODEL	3	12,13	.0190	.4456	.51	1	23
RSTR MODEL	3	11	.0115	.3116	.74	2	23
FULL MODEL	4	11,12,13	.0747				
RSTR MODEL	4	12,13	.0342	1.0062	.33	1	23
RSTR MODEL	4	11	.0262	.6035	.56	2	23

APPENDIX E

TABLE XII

Relationship between Skinner and Ruleg, Learner Characteristics, Unit Differences, Error Rate, and Achievement Levels

TABLE XII

Relationship between Skinner and Ruleg, learner characteristics, unit differences, error rate, and achievement levels

	Variables Dependent	Independent	RSQ	F-ratio	p	df_1	df_2
FULL MODEL	1	5,6,9,10,11,12,13,14	0.6106				
RESTRICTED MODELS							
1) delete program	1	9,10,11,12,13,14	0.6078	0.33	.5	1	46
2) delete unit	1	5,6, 11,12,13,14	0.3717	28.23	**	1	46
3) delete IQ	1	5,6,9,10, 12,13,14	0.5558	6.47	.01	1	46
4) delete sex	1	5,6,9,10,11, 14	0.5980	1.49		1	46
5) delete error rate	1	5,6,9,10,11,12,13	0.5824	3.33		1	46
FULL MODEL	2	5,6,9,10,11,12,13,14	0.4528				
RESTRICTED MODELS							
1) delete program	2	9,10,11,12,13,14	0.4519	0.07	.7	1	46
2) delete unit	2	5,6, 11,12,13,14	0.3560	8.13	**	1	46
3) delete IQ	2	5,6,9,10, 12,13,14	0.4004	4.4	.04	1	46
4) delete sex	2	5,6,9,10,11 14	0.4528	0			
5) delete error rate	2	5,6,9,10,11,12,13	0.4133	3.31	.07	1	46
FULL MODEL	3	5,6,9,10,11,12,13,14	0.7440				
RESTRICTED MODELS							
1) delete program	3	9,10,11,12,13,14	0.7374	1.19	.28	1	46
2) delete unite	3	5,6, 11,12,13,14	0.4221	57.8	**	1	46
3) delete IQ	3	5,6,9,10 12,13,14	0.6542	16.13	**	1	46
4) delete sex	3	5,6,9,10,11,12,13	0.7362	1.4	.2	1	46
5) delete error rate	3		0.7297	2.6	.1	1	46
FULL MODEL	4	5,6,9,10,11,12,13,14	0.4754				
RESTRICTED MODEL			0.				
1) delete program	4	9,10,11,12,13,14	0.4750	.02	.8	1	46
2) delete unit	4	5,6 11,12,13,14	0.2824	16.9	**	1	46
3) delete IQ	4	5,6,9,10 12,13,14	0.4659	0.8	.3	1	46
4) delete sex	4	5,6,9,10,11 14	0.4212	4.7	.03	1	46
5) delete error rate		5,6,9,10,11,12,13	0.4316	3.8	.05	1	46

APPENDIX F

TABLE XIII

Relationship of Program, Learner Characteristics, Error Rate to Levels of Science Achievement-LIGHT Unit

TABLE XIV

Relationship of Program, Learner Characteristics, Error Rate to Levels of Science Achievement-HEAT Unit

TABLE XIII

Relationship of program, learner characteristics, error rate to levels of science achievement - LIGHT Unit

	Variable						
	Dependent	Independent	RSQ	F-ratio	p	df_1	df_2
FULL MODEL	1	5,6,* 11,12,13,14	0.63				
RSTR MODELS							
a) delete IQ	1	5,6, 12,13,14	0.60	1.4	.2	1	19
b) delete sex	1	5,6, 11, 14	0.59	1.6	.2	1	19
c) delete error rate	1	5,6, 11,12,13	0.41	11.4	xx	1	19
FULL MODEL	2	5,6, 11,12,13,14	0.63				
RSTR MODELS							
a) delete IQ	2	5,6, 12,13,14	0.614	0.66	.4	1	19
b) delete sex	2	5,6, 11, 14	0.62	0.27	.6	1	19
c) delete error rate	2	5,6, 11,12,13	0.21	21.0	xx	1	19
FULL MODEL	3	5,6, 11,12,13,14	0.386				
RSTR MODELS							
a) delete IQ	3	5,6, 12,13,14	0.226	4.9	.04	1	19
b) delete sex	3	5,6, 11, 14	0.38	0.05	.8	1	19
c) delete error rate	3	5,6, 11,12,13	0.37	0.36	.5	1	19
FULL MODEL	4	5,6, 11,12,13,14	0.288				
RSTR MODEL							
a) delete IQ	4	5,6, 12,13,14	0.286	0.03	.8	1	19
b) delete sex	4	5,6, 11, 14	0.19	2.6	.1	1	19
c) delete error rate	4	5,6, 11,12,13	0.19	2.6	.1	1	19

*No significant program influence

TABLE XIV

Relationship of program, learner characteristics, error rate to levels of science achievement - HEAT Unit

	Variable						
	Dependent	Independent	RSQ	F-ratio	p	df_1	df_2
FULL MODEL	1	5,6,* 11,12,13,14	.410				
RSTR MODEL							
a) delete IQ	1	5,6, 12,13,14	.239	6.7	.02	1	23
b) delete sex	1	5,6, 11, 14	.385	.99	.3	1	23
c) delete error rate	1	5,6, 11,12,13	.402	.33	.6	1	23
FULL MODEL	2	5,6, 11,12,13,14	.377				
RSTR MODEL							
a) delete IQ	2	5,6, 12,13,14	.194	6.7	.02	1	23
b) delete sex	2	5,6, 11, 14	.376	.02	.9	1	23
c) delete error rate	2	5,6, 11,12,13	.374	.10	.7	1	23
FULL MODEL	3	5,6, 11,12,13,14	.581				
RSTR MODEL							
a) delete IQ	3	5,6, 12,13,14	.327	13.9	xx	1	23
b) delete sex	3	5,6, 11, 14	.549	1.7	.20	1	23
c) delete error rate	3	5,6, 11,12,13	.567	.7	.40	1	23
FULL MODEL	4	5,6, 11,12,13,14	.292				
RSTR MODEL							
a) delete IQ	4	5,6, 12,13,14	.25	1.4	.25	1	23
b) delete sex	4	5,6, 11 14	.21	2.6	.12	1	23
c) delete error rate	4	5,6, 11,12,13	.27	.7	.4	1	23

---

*No significant program influence

APPENDIX G

TABLE XV

The Relationship of Levels 1 and 2 on Achievement Level 3

TABLE XV

The Relationship of Levels 1 and 2 on Achievement Level 3

	Dependent	Independent	RSQ	F-ratio	p	df_1	df_2
		HEAVY					
FULL MODEL	4	2,3,5,6,11,12,13,14	.650				
Delete level 1	4	3,5,6,11,12,13,14	.584	3.977	.05	1	21
Delete level 2	4	2, 5,6,11,12,13,14	.599	5.07	.09	1	21
Delete programs	4	2,3, 11,12,13,14	.649	.169	.68	1	21
Delete IQ	4	2,3,5,6, 12,13,14	.620	1.77	.19	1	21
Delete sex	4	2,3,5,6,11, 14	.618	1.93	.17	1	21
Delete error rate	4	2,3,5,6,11,12,13	.646	.280	.60	1	21
		LIGHT					
FULL MODEL	4	2,3,5,6,11,12,13,14	.361				
Delete level 1	4	3,5,6,11,12,13,14	.352	.258	.61	1	17
Delete level 2	4	2, 5,6,11,12,13,14	.303	1.548	.23	1	17
Delete programs	4	2,3, 11,12,13,14	.360	.028	.87	1	17
Delete IQ	4	2,3,5,6, 12,13,14	.336	.668	.42	1	17
Delete sex	4	2,3,5,6,11, 14	.250	2.96	.10	1	17
Delete error rate	4	2,3,5,6,11,12,13	.335	.709	.41	1	17

Variable
2= achievement level 1
3= achievement level 2
4= achievement level 3
5,6 = program version
11 = intelligence
12,13 = sex
14 = error rate

APPENDIX H

TABLE XVI

Automated Text Tallies - Skinnerian Program

TABLE XVII

Automated Text Tallies - Ruleg Program

TABLE XVI

Automated Text Tallies - Skinnerian Program

1.00	Paragraphs per frame
1.58	Sentences per paragraph
11.23	Words per sentence
4.35	Letters per word
23.39	Percent words not in Suds dictionary (measure of general vocabulary difficulty)
288	Frames in the sample

98.96	Percent response frames
53.47	Percent frames with "related" terminology*
0.69	Percent frames with word(s) identical to resp. alternative:
2.78	Percent frames with "Boolean" resp. alternative (yes/no, true/false)
39.30	Percent response frames, response not last
93.40	Percent frames with word/phrase response alternative(s)

16.78	Percent "related" terms
4.27	Letters per "related" term
97.57	Percent frames with multiple occurrences of "related" terms
240	Cases of framewise overlap
111	Cases of consecutive overlap series

30.55	Percent integrator sentences
32.09	Percent signal sentences
5.93	Percent comparator sentences
13.12	Words per integrator sentence
13.62	Words per signal/comparator sentence
1.60	"Related" words per integrator sentence
1.81	"Related" words per signal comparator sentence

*"Related" terminology refers to the scientific and mathematical terms abstracted from behavioral objectives.

TABLE XVII

Automated Text Tallies - Ruleg Program

1.00	Paragraphs per frame
1.73	Sentences per paragraph
12.11	Words per sentence
4.36	Letters per word
23.99	Percent words not in Suds dictionary (measure of general vocabulary difficulty)

155	Frames in the sample

98.06	Percent response frames
43.23	Percent frames with "related" terminology*
2.58	Percent frames with word(s) identical to resp. alternative
1.94	Percent frames with "Boolean" resp. alternative (yes/no, true/false)
45.39	Percent response frames, response not last
89.68	Percent frames with word/phrase response alternative(s)

17.72	Percent "related" terms
4.07	Letters per "related" term
97.42	Percent frames with multiple occurrences of "related" terms
172	Cases of framewise overlap
83	Cases of consecutive overlap series

29.10	Percent integrator sentences
40.67	Percent signal sentences
10.07	Percent comparator sentences
12.77	Words per integrator sentence
13.72	Words per signal/comparator sentence
2.06	"Related" words per integrator sentence
2.24	"Related" words per signal/comparator sentence

*"related" terminology refers to the mathematical and scientific terms abstracted from behavioral objectives.

APPENDIX I

TABLE XVIII

Standard Weights Assigned to the 25
Readability Variables - Skinnerian and Ruleg Programs

TABLE XVIII

Standard Weights Assigned to the 25 Readability Variables* - Skinnerian and Ruleg Programs

Skinnerian Program		Ruleg Program	
Variable Number	Standard Weight	Variable Number	Standard Weight
1	0.18277245	1	-0.00579841
2	0.00000000	2	0.00000000
3	0.28545191	3	-0.16716149
4	0.23134649	4	-0.14968433
5	0.00000000	5	0.30950178
6	0.09758769	6	-0.60336497
7	0.04291700	7	0.37176365
8	0.10529069	8	0.00000000
9	-0.18017315	9	-0.01912271
10	0.08233432	10	0.02047304
11	0.01367922	11	0.17193178
12	0.06602573	12	-0.26959749
13	0.02303355	13	0.09922112
14	0.07785489	14	-0.30187925
15	0.12903041	15	-0.25758785
16	0.01356095	16	-0.11935410
17	-0.13337785	17	-0.06060466
18	0.19619866	18	0.15160406
19	0.04090694	19	-0.23824761
20	-0.06482657	20	0.05828184
21	0.29207201	21	0.01445657
22	0.01850725	22	-0.28683381
23	-0.02010439	23	0.03453030
24	0.02835074	24	0.74415952
25	-0.23622038	25	-0.1442081

RSQ = 0.2763

RSQ = 0.449

*See Section II, Chapter III for variable identification.

APPENDIX J

TABLE XIX

Analysis of the Effects on Achievement Levels Attributed to Branch Adaptations

TABLE XIX

Analysis of the Effects on Achievement Levels Attributed to Branch Adaptations

	Variables						
	Dependent	Independent	RSQ	F-ratio	p	df_1	df_2
FULL MODEL	1	2,5-12	.80				
RSTR MODEL	1	2,5,9-12	.76	3.69	.04	2	35
FULL MODEL	1	3,6-12	.91				
RSTR MODEL	1	3,9-12	.88	5.69	xx	2	38
FULL MODEL	1	4,6-12	.90				
RSTR MODEL	1	4,9-12	.80	2.40	.11	2	36
FULL MODEL	2	6-12	.62				
RSTR MODEL	2	9-12	.52	6.04	xx	2	37
FULL MODEL	3	6-12	.54				
RSTR MODEL	3	9-12	.42	3.02	.04	3	36
FULL MODEL	4	6-12	.41				
RSTR MODEL	4	9-12	.20	4.3	.01	3	36

APPENDIX K

TABLE XX

Standardized Weights Associated with the Readability Analysis of the Programed Materials, Branching Version

TABLE XX

Standard Weights associated with the Readability Analysis of the Programed Materials, Branching Version

Variable	Standard Weight
Frame number	0.6727
Paragraphs per frame	0.0000
Sentences per paragraph	-0.3411
Words per sentence	0.3615
Letters per word	0.0546
Vocabulary difficulty	-0.0428
Frames per page	0.4772
Per cent of response frames	-0.1863
Per cent of frames with technical terms among response alternatives	0.0825
Per cent of frames with word in frame identical to response alternative	0.2939
Per cent of frames with yes-no ar true-false response alternative	0.0138
Frames in which response is placed within sentence	-0.0872
Per cent of frames with 3 words or less as response alternative	0.0927
Average number of technical words	0.1502
Letters per technical word	0.1606
Per cent of frames in which the same technical term appears more than once	-0.0293
Average no. of frames in which the same technical word appears consecutively	0.1631
Average no. of consecutive instances of technical word overlap	-0.2458
Integrator sentences: this, that, it	-0.0531
Signal sentences: because, but, although, as, since, when, then, next, etc.	0.0495
Comparative sentences: than	0.1146
Words per integrator sentence	0.1080
Words per signal and comparative sentences	0.2923
Technical words per integrator sentence	-0.1703
Technical words per signal and comparative sentences	-0.3482

APPENDIX L

Computer Program Quickly

Prototype

APPENDIX I.

COMPUTER PROGRAM QUICKLY
PROTOTYPE

Character Set

The acceptable characters in a "book" are all the 63 characters permissible in Burroughs Extended Algol. This language defines as ALPHA characters all characters which are either the digits zero through nine (0,1,2,.........,9), or letters of the alphabet (A,B,C,....Z). All the characters which are non-ALPHA are SPECIAL characters.

Of the SPECIAL characters, seven were given defined meanings for Quickly. These are reserved as controls and are: . (period), - (hyphen), = (equal sign), / (slash), > (greater than sign), * (asterisk), b̸ (blank).

All SPECIAL characters which are not one of the seven controls are treated as if they were the character blank.

Words

A word, to QUICKLY, is a set of characters in a particular order. Words are delimited by blanks or control characters.

Sentences

Sentences usually consist of no words followed by a period, or any number of words followed by a period. Sentences are ended by the characters: . (period), / (slash), * (asterisk), and > (greater than).

Frames

Seven different frame types are recognized. These are Response, Structured Response, Free Response, Non-Response, Review, Dialpoint, and Non-Dialpoint Frames. (A frame includes tally information and paragraphs.)

Paragraphs

A paragraph is a group of sentences. The paragraph begins with the character / and may be terminated by any or several of the characters / (slash), * (asterisk), > (greater than) and . (period).

Page Number

If the <page number> is not present, the current page number will be incremented by 1. If no page number is specified for the very first page, it will be assumed 1. If a <page number> is present it replaces the current page number.

(APPENDIX 1.)

Books (Learning Units)

A "book" for QUICKLY is a standard ALGOL file labelled "xxxxxxx/" "TEXT". It consists of one or more pages as defined above, punched on cards in columns 1-80. This book is terminated by an END OF FILE control card.

Responses Responses are characteristic of but not restricted to Programmed and Computer Assisted Instructional materials.

Responses are groups of words bracketed by * marks. These word groups may also be terminated by //* control characters if desired.

Output

QUICKLY "reads" a book and sorts all words onto two lists. One is a list of all words bracketed as responses and the other is a list of non-response words. Lists are in alphabetical order. A word is printed, then the locations of its occurrences are indicated as ⟨page number⟩ : ⟨frame number⟩.